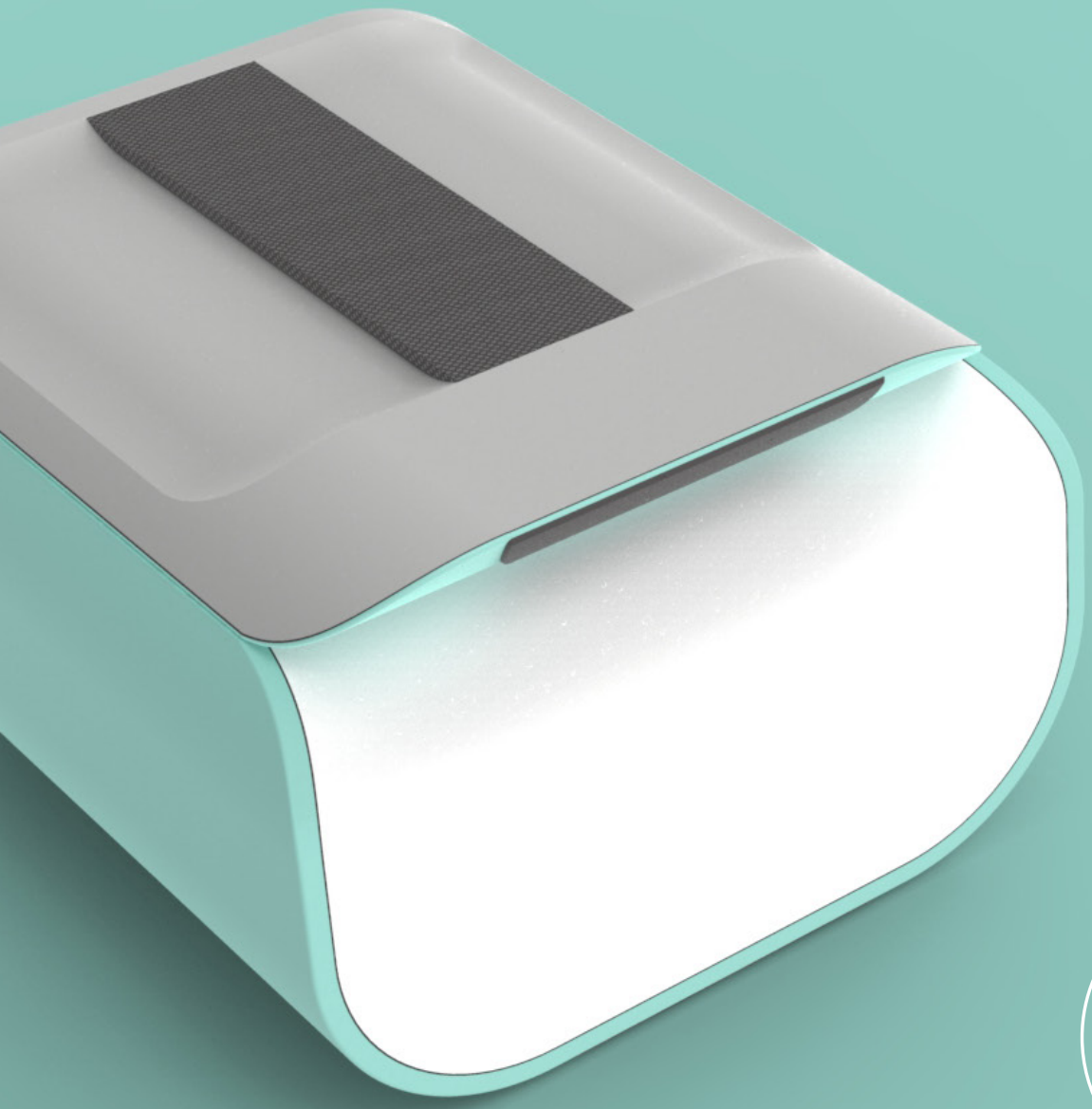
Master Thesis | Eileen Huang

staying alive

Developing a defibrillator for everyday portability



LUND UNIVERSITY

Staying alive - Developing a defibrillator for everyday portability
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Degree Project for Master of Fine Arts in Design
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ABSTRACT

In today's society, sudden cardiac arrest is one of the leading causes of death worldwide. Automated External Defibrillators are often found in public spaces, but a majority of sudden cardiac arrests occur in home environments. Even so, the current options for personal defibrillators are severely limited and not adapted for everyday portability. The purpose of this project was to design an Automated External Defibrillator which addresses the needs and demands of a portable personal defibrillator, and eases the daily lives of the intended users. The project was executed with a strong focus on user research, using methods such as surveys, in-depth interviews and mockup testing - with inexperienced, experienced and expert users alike. This user focused research led to the development of an Automated External Defibrillator which improves the user experience through tactile and semantic principles, as well as optimizing portability and understandability. The design was then visualized through analogue and digital sketches, foam mockups, virtual 3D models, and digital renderings.

KEYWORDS

design, medical, healthcare, emergency, defibrillator, portable, IoT, UX, UI, app

ACKNOWLEDGEMENTS

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I would also like to thank Catarina Rodrigues, Viktor Levin, Amanda Ekstedt and Thomas Triangeli for participating in the User testing. Furthermore, thank you to the four in-depth target group participants for their continuous feedback, as well as Yoatzin Alonso, Peter Handrup and more for offering their expertise and insights.

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1.0 INTRODUCTION

This project started with an interest and fascination with Medical Design.
Having parents working in the Medical field, with my Mother working as a drug researcher at Astra Zeneca and my Father being a surgeon, I used to think that I would end up in that field as well. Today I am more than convinced that I have found the right path for me in Industrial Design, but this personal background opened my eyes to Medical Design and the many areas in this field, in which there is true potential for improving the User Experience through the design decisions that we make.

Looking at the many varieties of Medical Products on the current market, the aim was to identify an area in which the usage of the current product was clearly lacking, or where there was an opportunity to expand the market but not yet many competitors doing so.

This lead me onto the path of Automated External Defibrillators(AEDs for short), also known as heartstarters. AEDs are perhaps one of the most commonly seen Medical Products in public spaces today, with them commonly occuring in places such as airports, gyms and on trains. Even so, I personally had very limited knowledge about AEDs and how they are actually used. With this in mind, I wanted to explore if this notion was shared with others, and if so, how AEDs could be improved in order to actually be used, and specifically target those who will most likely need them the most.

1.1 Objective

The objective of this project was to design a portable Automated External Defibrillator mainly targeted towards users with elevated risks of Sudden Cardiac Arrest, and their relatives.

1.2 Problem formulation

How do you design an Automated External Defibrillator that is portable enough to be taken with you everywhere, while also improving the Usability and Functionality?

1.3 My design vision

In recent years, I have become increasingly aware of how powerful design can be, especially when used as a tool to reflect the users' and stakeholders' points of view; enabling us to influence their lives to the better. This notion is one that I am eager to bring into all my industrial design projects.

My goal for my designs, are for there to be intent behind every design element or component, and for the design to be grounded in a strong Usability focus. To achieve this, research and continuous user testing and evaluation is something that I highly value in any project, making sure to really learn about the users and their needs, in order to not let any personal assumptions be the main drivers of the design outcome.

2.0 METHODS

This project made use of several design methods, with a strong focus on ones concerning research.

Market analysis: Identifying and analyzing products currently on the market, in order to understand functionality and pain points.

Desktop and Literature research: Gathering knowledge and insights into the more technical and medical aspects of the product technology and usage.

Educational course: Participation in AED course in order to better understand the functionality and process of using existing products.

Expert interviews: Interviewing medical staff and educators in order to gather their expertise and professional insights into the product and its usage.

Target group interviews: Interviews aimed at understanding the target group's current situation and pain points, as well as their wishes and needs.

Surveys: Getting a quantative understanding of the current perceptions and experiences of existing products, as well as identifying desirable or problematic aspects of them.

Brainstorming: Freely generating ideas in group without judging, creating a base of different ideas to continue developing.

Love & Hate: Identifying positive and negative aspects of an idea, in order to understand which features to further develop.

Analogue and Digital sketching: Main ideation method used, with a focus on quantative ideation, and evaluation of ideas and details.

Mock-ups: Getting a sense of shape, volume and dimension, as well as enabling basic testing of the functionality and usage process.

User tests: Testing and subsequent evaluation of mockups in order to collect user input and feedback for further development.

CAD-models and Renders: Ideation, as well as the main method of vizualizing the final design in a context, since physical final prototypes could not be made due to workshops being closed because of COVID-19.

3.0 RESEARCH I.0

Initial desktop/literature research, survey and interviews in order to gather knowledge and insights about Automated External Defibrillators devices and usage, the current product market and potential problem areas of existing products.

3.1 Initial research questions

How does an AED work?

Are existing AEDs easy for the user to understand?

In which situations would you need to use an AED?

Which are the pain points of existing AEDs?

3.2 Sudden Cardiac Arrest

Sudden cardiac arrest, or SCA for short, is among the leading causes of death worldwide[1], and in some countries, like the U.S., it is the number one leading cause of death - causing more deaths than breast cancer, colon cancer, motor vehicle accidents and diabetes combined[2]. Unlike a heart attack, in which the blood flow to the heart becomes blocked, cardiac arrest occurs when the heart stops beating. The onset is sudden and comes without warning, and can occur in people of all ages, even if they appear to be healthy.

Early defibrillation combined with CPR can improve survival rates to as high as 74% when defibrillation is provided within 3 minutes of collapse[3]. Without immediate treatment, the chances of surviving sudden cardiac arrest drops 7-10 percent with every passing minute[4], making response time an extremely critical factor.

In Sweden, the average response time for ambulances is 12 minutes, with only one single municipality having an average response time below 10 minutes(Tranås municipality, 8 minutes[5]). This is a national average that has doubled in time the last 30 years[6], and many parts of Sweden has far longer response times than the national average. Looking at other countries, The United Kingdom has a statutory law, stating that 75% of all severely ill or hurt patients in both rural areas and in cities, shall be reached by ambulance within 8 minutes. Similar laws also exist in Italy. In the U.S. and Canada, the national goal is for 90% of the most severe cases being reached by ambulance within 10-15 minutes[7]. According to National Safety Council, America's leading nonprofit safety advocate[8], it takes paramedics an average of 8 to 12 minutes to respond. Australia also have similar guidelines as the U.S. and Canada.

With these numbers in mind, it is clear that sudden cardiac arrests require quick response times, which often can not be met by professional emergency responders. Quick access to an automatic external defibrillator by an engaged bystander could increase the odds of survival from about 5% to 40% and higher.

Sudden cardiac arrest can happen to anyone, even those who are seemingly healthy.
Between 300,000 and 400,000 people experience sudden cardiac arrest in a non-hospital environments every year. For example, the majority of out-of-hospital cardiac arrests occurres at home (81.8%), and

1 https://www.aerjournal.com/articles/sudden-cardiac-death-and-arrhythmias
2 https://www.sca-aware.org/about-sca
3 Valenzuela T.D. et al. Outcomes of rapid defibrillation by security officers after cardiac arrest in casinos. New England. Journal of Medicine. 2000; 343:1206-1209.
4 https://www.nsc.org/safety-first/who-will-suffer-a-cardiac-emergency
5 https://ka.se/2020/01/31/har-finns-sveriges-snabbaste-blaljus/
6 https://www.emergency-live.com/sv/ambulans/f%C3%B6rkorta-ambulansens-svarstid-%C3%B6kar-%C3%B6verlev-naden-vid-hj%C3%A4rtstopp-utanf%C3%B6r-sjukhuset-en-studie-fr%C3%A5n-sverige/
7 https://www.s112.se/2017/09/17/13451/
8 https://www.nsc.org/

44.3% were in the presence of bystanders[9]. the U.S. Occupational Safety and Health Administration also estimated that about 13% of total deaths caused by SCA occur in the workplace[10]
Furthermore, it is estimated that widespread availability of AEDs could save as many as 40,000 annually in the U.S. alone[11], and thus even more, seen worldwide.

3.3 Market analysis

As a starting point for the AED research, the focus was on the AED brands which are approved by the FDA (U.S. Food & Drug Administration). The reason behind this choice was due to North America dominating the External Defibrillator market[12] in recent years. This is also a market which is quite clearly regulated, whereas in Europe, the regulations can differ quite widely between countries[13].

According to the FDA website, only 6 brands of AED:s are currently approved[14]. These brands are:

- Cardiac Science Corporation
- Defibtech, LLC
- Heartsine Technologies, LLC
- Philips Medical Systems
- Physio-Control, LLC
- ZOLL Medical Corporation

Among these 6 brands, there are a total of 29 approved models. Since this project was aimed at private consumers, the models specifically targeted towards first-responders and medical professionals were removed from the initial market analysis selection.

With this selection made, 11 models were left. These 11 models included both automatic and semi-automatic versions, with the difference being that semi-automatic AEDs require the user to press a button in order to administer a shock, while fully automated AEDs administer the shock without needing additional action from the user[15]. In addition to these models, the Philips HeartStart FR3 was also added, even though it is targeted towards professional use, since I found the compact and simplified design interesting as a source of inspiration.

With this overview, it was possible to identify several common nominators and issues among the designs. With few exceptions, the majority of the products require an external case for storage of pads and other accessories. The general form language is bulky and square, while the color of either the product or its case is usually attention grabbing. A few models seem to be striving for a more empathetic design, but the majority would be interpreted as having an non-empathetic and industrial style.
There is also a big inconsistency in how instructions are conveyed, ranging from cluttered visual instructions, to text instructions with tiny fonts. All in all, there is a big room for improval in terms of understandability and connection with the user.

9 https://www.healio.com/news/cardiology/20181112/cpr-education-laws-increase-survival-rates-in-outofhospital-cardiac-arrest
10 https://ohsonline.com/Articles/2004/09/The-cost-of-cardiac-arrest-in-the-workplace
11 https://smhs.gwu.edu/heartandvascular/restart-dc/aeds-sca-facts
12 https://www.fortunebusinessinsights.com/industry-reports/external-defibrillator-market-100949
13 https://eena.org/document/aed-legislation-document/
14 https://www.fda.gov/medical-devices/cardiovascular-devices/automated-external-defibrillators-aeds
15 https://www.physio-control.com/uploadedFiles/Benefits%20of%20Fully%20Automatic%20Defibrillators.pdf

Cardiac Science Co.
PowerHeart G3 Plus

Physio-Control
LIFEPAK 1000

Physio-Control
LIFEPAK CR Plus

Cardiac Science Co.
PowerHeart G5

Defibtech
Lifeline

Physio-Control
LIFEPAK CR2

Philips
HeartStart FRx

ZOLL
AED Pro

Heartsine Techn.
Samaritan PAD 360P

Philips
HeartStart FR3

ZOLL
AED Plus

Heartsine Techn.
Samaritan PAD 450P

3.4 AED components

Most AEDs targeted towards non-professionals consist of the same basic components, with some models having extra add-ons. The shape, layout and level of detail of the components can vary depending on model, but the functions remain largely the same.

main component

optional add-on

3.5 AED technology

Today, Automated External Defibrillators are a common sight in public spaces such as airports, gyms and malls. But the AED as we know it today was introduced as late as in 1996, with the launch of the AED "Forerunner" from Heartstream[1].

Before this, *traditional defibrillators were used in operating rooms. Large machines, capable of delivering enormous shocks—up to 350 joules and perhaps 20 kilowatts using waveforms associated with an RLC (resistance, inductance, capacitance) circuit*[2]. This type of defibrillators is still used in operating rooms, but differentiate themselves from AEDs in several ways. Apart from requiring a bigger power source in order to deliver these enormous shocks, the joules of the shocks given are determined and manually adjusted by the medical personnel. As mentioned, they also use RLC circuits, which means that they have a single phase—in essence, they give out one big surge of power.

Before Heartstream's Forerunner, the common home-use alternative for defibrillators were implantable defibrillators, which used tiny batteries and delivered significantly smaller shocks than traditional defibrillators. They managed to do that by using biphasic waveforms, which were much lower energy and worked just as well. This was the inspiration for the Forerunner, which also used biphasic waveforms, which delivers the shock in two phases, instead of one phase as with RLC circuit technology. The shock given with a biphasic defibrillator uses 30 to 40 percent less peak current than a RLC defibrillator does at the same applied energy level[3], meaning that it requires less energy to perform the shock, and thus can be made smaller as well as battery driven. Though RLC circuit AEDs also exist, biphasic waveform AEDs are clearly the more common alternative on the market due to its portability advantages[4].

- FDA-approved AEDs all use variations of biphasic technology, often their own trademarked versions
- Automated external defibrillators deliver their shocks in two types of protocols: escalating and non-escalating (or fixed)[5]
- Most AEDs will perform daily self checks to ensure functionality
- As a standard, AEDs are programmed to deliver adult-dose shocks with energies ranging from 150 to 360 Joules[6]
- Pediatric setting will adjust to 50 joules[7]
- Using accelerometer technology, a sensor inside the electrode pad can capture the rate and depth of each compression during CPR. This is used in AED models such as ZOLL's AED Plus® and AED Pro®[8], and Cardiac Science's Intellisense (CPR sensor product, not AED)[9]
- Heartsine's Samaritan PAD 500P uses Impedance Cardiogram (ICG) analysis, embedded into the software, which guides the user in the required force and speed of compressions for the victim. The ICG measures impedance changes in the chest cavity, which helps determine effective CPR[10].

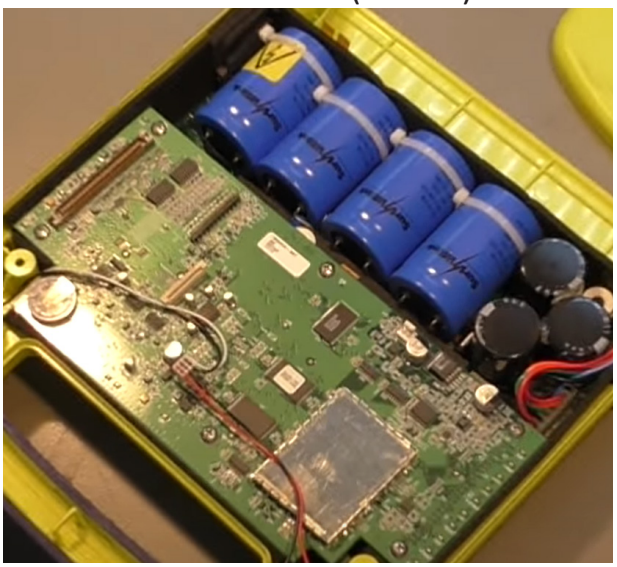
1 https://spectrum.ieee.org/the-consumer-electronics-hall-of-fame-heartstream-forerunner
2 https://spectrum.ieee.org/the-consumer-electronics-hall-of-fame-heartstream-forerunner
3 https://www.hmpgloballearningnetwork.com/site/emsworld/article/10324825/biphasic-defibrillation-shape-resuscitation-today
4 https://wwww.mindray.com/nl/aed/Blog_How_to_Differentiate_between_Monophasic_and_Biphasic_AED_Defibrillators.html
5 https://www.aedbrands.com/resources/choose/escalating-and-non-escalating-aeds/
6 https://www.ilcor.org/data/ILCOR-AED-children.pdf
7 https://www.heartsmart.com/philips-heartstart-onsite-pads-cartridge-pediatric-p
https://www.zoll.com/medical-technology/defibrillation/pediatric
8 https://www.zoll.com/medical-technology/cpr/real-cpr-help
9 https://www.cardiacscience.com/products/cpr/
10 https://heartsine.com/product/p/500p/

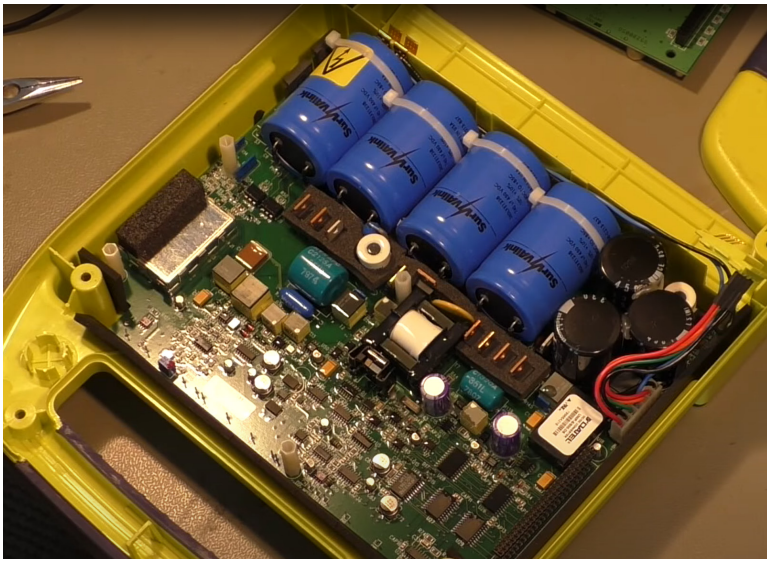
3.6 AED technical components

In order to get a more technical understanding of AED technology, further research was made into the inner components of AEDs. The main resource used for this was youtube videos, showing the full process of taking apart devices and analyzing the individual components inside. With limited previous knowledge of technical components, this was a very helpful way of learning and understanding what is needed in order to deliver a shock to a patient, as well as understanding what needs to be able to fit inside a device and how to organize those components.

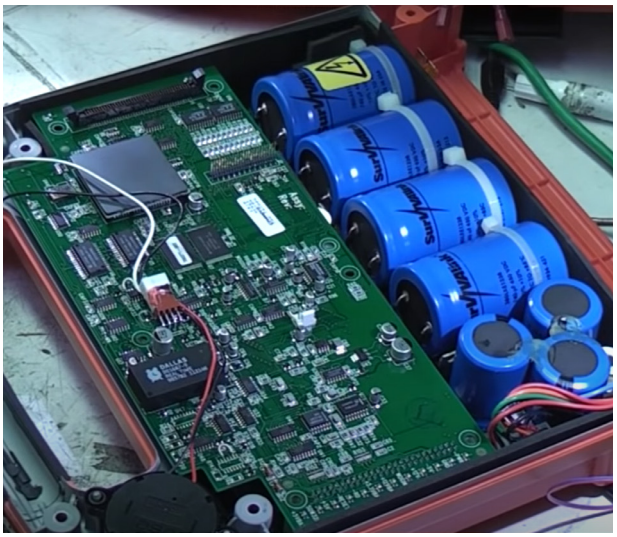
To summarize, AEDs usually have two motherboards layered on top of each other. The energy source used for powering the device is usually in the form of capacitors (shown in blue on the pictures below). These capacitors are in turn powering one or multiple DC-DC convertors, which converts the direct current from the capacitors into direct current used to deliver the actual shock. Some of the individual components are also connected to their own separate capacitors. As a standard, AEDs also have built-in real-time clocks, as to not be dependent on any network. Apart from this, there is also a processor for the software, which controls the main functions of the device, as well as drivers, isolators, transistors and extensive foam and rubber padding. This padding keeps everything protected and in place when the AED is moved or tossed around, absorbing any shocks.

What's inside an AED? (PWJ46)[1]





Defibrillator teardown[2]



1 https://www.youtube.com/watch?v=3VRjvAP2O60&t=1439s
2 https://www.youtube.com/watch?v=pn-Wv9YAfv0&t=739s

3.7 AED course

In order to better understand how an AED works in practice, and not just in theory, I signed up for a 3-hour AED course held by the Red Cross in Malmö.

This course was very helpful in giving me hands-on knowledge of how to use an AED, but also in highlighting some of the pain points. As most of the other participants in the course had never before used an AED either, the questions they asked also gave me insights into which parts of the usage were intuitive, and which were confusing or needed further explanation.

Powerheart G5 Semi-Automatic Non CPRD Defibrillator

3.8 AED user journey

1. Case is opened
2. User presses green ON button (or pulls lever)
3. Voice commands start

Voice instructions:
4. Remove clothing
5. Remove adhesive protection on pads
6. Place pads as shown on illustration on bare skin (first right (patient's left) then left (patient's right)
7. AED analyzes heart rhythm
8. Either press orange/red button for electrical shock, or shock is not advised
9. Clear away from patient
10. Shock is administered by AED
11. It is now ok to touch patient
12. Reminder to contact emergency services
13. CPR is advised
14. Press blue info/instructions button for CPR instructions
15. CPR rhythm and breathing instructions are given x2
16. Instructed to keep on giving CPR on own accord

3.9 AED course - Key insights

By observing and listening to the fellow course participants, it was possible to identify some key usage issues. The main insight related to timing. As our course instructor shared, in an emergency situation even seconds can feel like an eternity, due to the adrenaline heightening your senses and keeping your body in a high-alert mode. With this specific AED model (and a majority of other models for amateur use on the market), the instructions are given mainly through voice command. These commands are given to the user according to a predetermined timing, meaning that no matter how fast or slow the user performs the instructed action, the timing of the voice commands will be the same. Observations made showed that the timing of the AED used was noticably slower than the speed of which the actions were performed, leading to the user feeling insecure about when another command would follow, or if the commands had paused due to the action being performed incorrrectly. One can only imagine that this reaction would be even more amplified during a real life emergency situation, where the adrenaline as mentioned would likely create an even more pressing sense of urgency.

3.10 Survey I

To gauge the understandability and general knowledge and opinions of the current market competitors, a survey was made with focus on understanding how aware the participants were of AEDs, and how well they understood the current competitors both in terms of physical design and visual/written instructions.

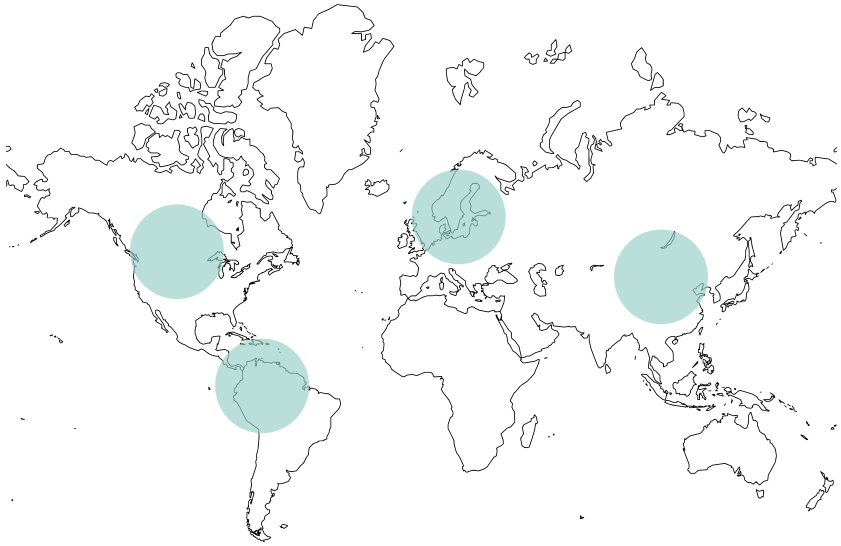
The survey also explored how willing the participants imagined that they would be to use an AED in an actual emergency situation, and which factors might make them more or less willing to do so. The survey was mainly sent out through social media channels such as facebook, but still managed to reach a quite wide demographic range

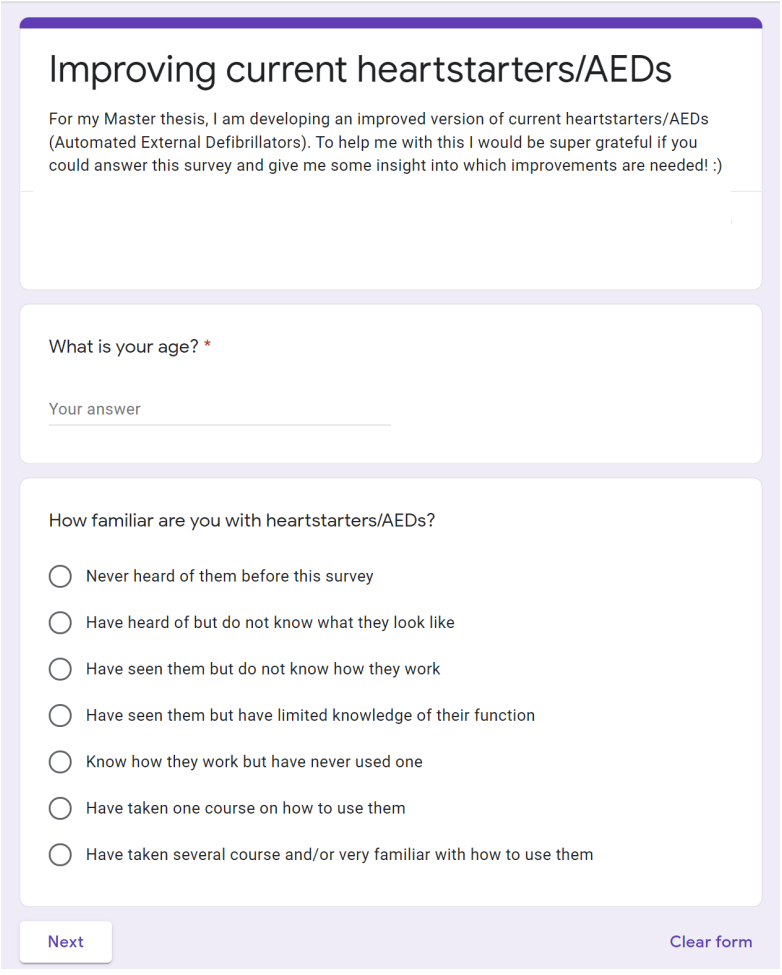
31 participants

18-60 years old

varying experience

varying background





Improving current heartstarters/AEDs

For my Master thesis, I am developing an improved version of current heartstarters/AEDs (Automated External Defibrillators). To help me with this I would be super grateful if you could answer this survey and give me some insight into which improvements are needed! :)

What is your age? *

Your answer

How familiar are you with heartstarters/AEDs?

- Never heard of them before this survey
- Have heard of but do not know what they look like
- Have seen them but do not know how they work
- Have seen them but have limited knowledge of their function
- Know how they work but have never used one
- Have taken one course on how to use them
- Have taken several course and/or very familiar with how to use them

Next Clear form

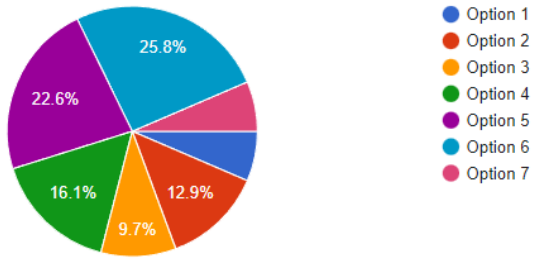
Online survey, Google forms

16 main questions

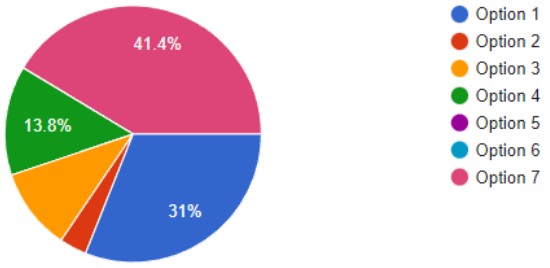
11 add-on questions
(personal AED experience)

Multiple choice and written answers

Here are 6 of the most common heartstarters/AEDs on the market. Which of these do you think you would choose to use in an emergency situation?



Which one do you think would be your last choice in an emergency situation?



Option 1

Option 3

Option 5

Option 7

Option 2

Option 4

Option 6

The two questions evaluating the preferences among the leading models on the current market showed a preference for Option 6 and Option 5, while a clear majority of respondents chose Option 7 and Option 1 as their last choice to use. Following these two questions, they were asked to elaborate on the reasons behind their choices, in order to understand what makes an AED more or less inviting to use. A compilation of some of the most interesting quotes are seen here, with top rated models on the left and lowest rated models on the right, color coded by option number.

It looked like the most easy to understand

Clearest and simplest visual instructions of use.

Looks easy to use, cuz I dont know what they do yet. So i go for the one with least buttons etc

Not to many things going on just right on point on what to do fast and easy,step-by-step. What is helping to make it look easy to use in a fast way is also its choice of where the colors are placed to make the eyes go where it should, in an orientated way. It also seems easy to carry, in it's size and with the handle.

Looks mostly like the one I have trained with

Most familiar, doesn't look so complicated

Looks easy to understand

It looks straightforward to use

The instructions are very long, if I was stressed I'd probably find it harder to follow

The instructions are small and all over and i dont understand why its shaped like that

It's to much information to handle in a emergency situation. Makes me feel stressed and afraid of not understanding the procedure in the right way.

Not clear what the first step is, where the patches are supposed to be put on the body.

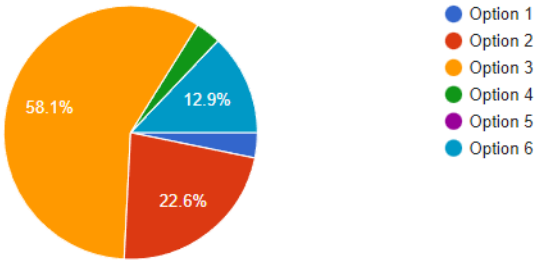
Unclear. Something that looks like an instruction book with disclaimers etc. Don't know if I have time to read it.

Looks chunky and complicated

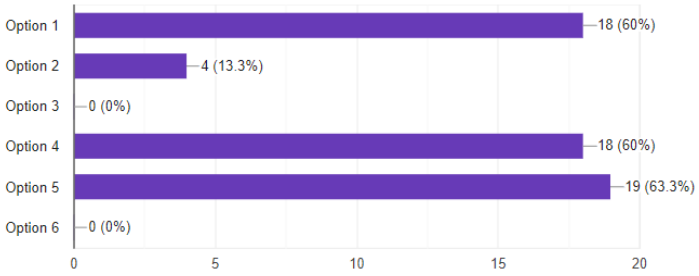
Looks ugly and complicated

Seemingly small printed instructions, with limited visual guiding.

Which of these graphic instructions do you think gives the best/clearest information?



Are any of these instructions unclear or confusing to you?

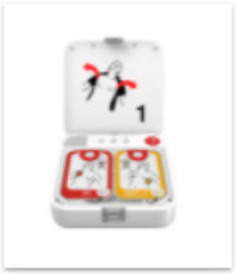


Option 1

Option 3

Option 5

Option 2



Option 4

Option 6

Since instructions are a critical part of AED understandability, the goal with these questions was to identify how respondants perceive current AED instructions.

Option 3 was clearly preferred by the respondants, while Option 2 was quite popular as well. Looking at these two options, what they have in common is that they both have a limited amount of instruction steps, which are each divided into big fields, and these fields are also marked with different colors for each step. These 3 fields also have the same shape and layout in both Option 3 and Option 2, starting with a bigger rectangle on the top, and then two squares underneath. This clearly indicates that the bigger rectangle is where the instructions start, and then relies on the western reading logic of reading from top to bottom and left to right.

In the illustration for Option 3, there is also a clear context to the instructions, with hands and user in the instruction picture, which might be why it is rated as even more understandable than Option 2, which mainly relies on arrows to show the intended actions.

As for the lowest rated instructions, Option 5 was clearly the one least preferred by the survey participants. For this instruction, there is only one single illustration, printed on the electro pad packaging. This single illustration only shows how to open the packaging, but does not offer a clear overview of the AED use itself.

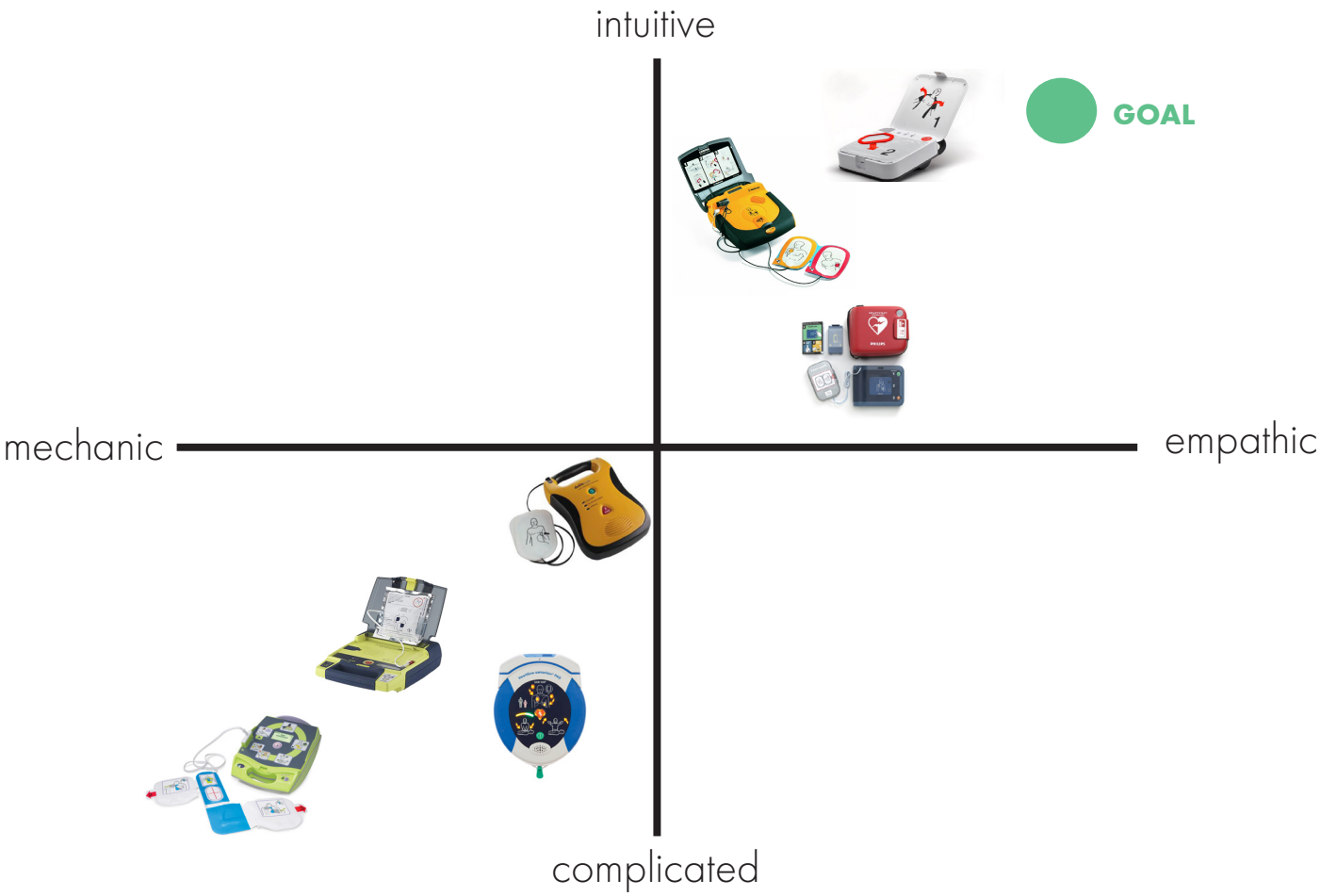
3.11 Survey I results

As can be seen in the survey responses to question 29, understandability, simplicity and ease of use was a crucial factor for the participants, in deciding which AED model they would rather use in an emergency situation. The two models that were thought to achieve these qualities the best were Option 5 (Defibtech) and Option 6 (ZOLL). Interesting enough, the other model from ZOLL (Option 7) was overwhelmingly chosen as the least preferred, with 41.4% saying it would be their last choice out of all the models. Option 1 from Cardiac Science Corporation was also the last choice of many participants.

Here the answers show that these models were interpreted as being too “messy” and “complicated”, both based on the amount of physical parts, as well as the amount of instruction steps and how these steps were arranged and presented. This complexity was also increased if the instructions included a lot of text rather than illustrations.

3.12 Positioning

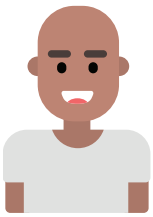
Based on the survey results, the main private consumer-targeted models of each of the 6 FDA-approved brands were positioned on a perceptual map, in order to visualize where I wanted to go with my product, and which current products were furthest from or closest to that goal.



3.13 Interviews I

After gathering some quantitative insights from the survey, the goal was to additionally gather more in-depth qualitative insights to further understand the issues and potential in current AEDs. For this purpose, three in-depth interviews were conducted, where the participants got to talk about their personal AED experience, answer the survey questions, and then answer more in-depth interview questions depending on their answers. They were also asked about potential improvements they could imagine for current AEDs and in which areas they thought there could be potential for new or specialized AED models.

Interview 1: Cardiologist



Through mutual contacts, I had the possibility of interviewing Yoatzin Alonso Lopez, a cardiologist working in Malmö, Sweden. Apart from being a cardiologist, he has also been teaching courses in AED since 2014/2015, so it was very helpful learning about his professional experience, knowledge and opinions on AEDs. He also shared that during his early days of medical studies, he had once witnessed someone suffering a sudden cardiac arrest in a public space (the cinema where he was working at the time), and where an AED had to be used. In that case there happened to be several doctors among the visitors, so he himself grabbed the AED and started it up, but another doctor performed the actual resuscitation.

SCA situations

- A real life SCA situation can be very chaotic. Removing clothing can be quite violent and even with professionals around, there is a lot of stress and a general feeling of panic.
- If there are a lot of bystanders, that can add to the chaotic feeling of the situation, even if they are just trying to help.
- One of the main challenges in a SCA situation as a non-professional, is to keep your calm and figure out what to do first.
- If you are alone when someone has a SCA, having to coordinate getting an AED, giving CPR, listening to the voice instructions and talking with a emergency call operator all at the same time can be extremely stressful and disorienting.

AED functionality

- When using AEDs, it is actually common that the machine will analyze the heart rhythm several times during the usage.
- Between each heart rhythm analysis, the machine will instruct the user to do CPR for ca. 2 minutes, before analyzing again.
- Even though the AED will continously analyze the heart rhythm while connected to the patient, it might not give an electric shock, if there is still a pulse detected.
- Even after giving an electric shock, the AED will continue giving more electric shocks, if a pulse still is not detected by the next heart rhythm analysis.
- An AED is a device which cannot be dangerous or used as a weapon. It can only be used for its' intended purpose and will not give a shock if not needed.
- Most commercial AEDs are quite similar in their functionality, but some are less intuitive in their layout. For examply buttons can be too small relative to the size of the AED.

Improvement needs

- The most important thing is to have continuity in AED courses and keeping your knowledge/memory current. Preferably at least once every year or even more often if you work somewhere crowded.
- People who have not taken an AED course usually are completely unaware of how AEDs work
- If there is an instruction screen it needs to be big and visible. If it's to small to be legible, then it works counterproductively and confuses/stresses the user rather than helps them. But generally he does not find screens to be neccessary, unless they are animations or showing CPR rhythm.

- It is better to limit the amount of buttons and information on the device.
- Buttons should be bigger and colour coordinated
- The timed voice instructions are always slower then the time it takes to perform the actions, so there is always a bit of waiting time in between actions. This can cause insecurity.
- Encouragement improves the quality of the actions performed, so encouragement is very important.

Interview 2: Lifeguard

The second interview was with Peter Handrup, a former lifeguard, who had worked at an indoor swimming pool for several years. This work included regularly taking AED and CPR courses, and his estimation was that he had taken around 15 courses in total. But he had never experienced a real life SCA emergency situation. At the swimming pool where he previously worked, they had two types of AEDs, one targeted towards amateurs and one targeted towards first responders. Here it was particularly interesting hearing about the differences between personal and professional portable devices and what were the pros and cons of each.

First-responder AED

- No visual instructions
- No voice instructions
- Shock strength can often be adjusted by the user

General

- If you are familiar with AED use, having to follow and wait for voice instructions can be stressful, since you cannot adapt them to your preferred pace.
- If the voice instructions are too slow you might start to wonder if you did something wrong.
- In an emergency situation when you are pumped up on adrenaline, you are performing every action very fast, and your time perception is different.
- When you are stressed and nervous, you might use more force, so it is really important that any closure is sturdy enough for rough handling.
- Even the time it takes to open a zipper can feel like wasted time, fast and straightforward closures are preferred.
- In a stressed situation, it's important to minimize and clarify the information that is given. Buttons and pictures need to be big and clear, with minimal amount of text.

Interview 3: Inexperienced

After interviewing two more experienced users, a completely inexperienced user was interviewed in order to widen the perspective of the insights. Sara Johannesson, a Maths student with no experience, and limited knowledge of AEDs, was interviewed for this purpose. She was generally aware of the existence of AEDs, especially in places such as the gym and at airports, but had no concrete knowledge of how these are used, more than knowing that they are supposed to shock the heart.

- Would be uncomfortable/insecure using an AED in an emergency situation
- Would not be sure where to find the nearest AED
- Worried about giving a shock if not actually needed and doing more harm
- Not aware of the analyzing function which is present in most amateur AEDs
- Taking in instructions/new information in a stressful situation can be really difficult
- Would not dare to use an AED on a child
- First reaction to an SCA emergency situation would likely be to look to others for help, hoping someone else would step in

3.14 Non-FDA approved competitors/concepts

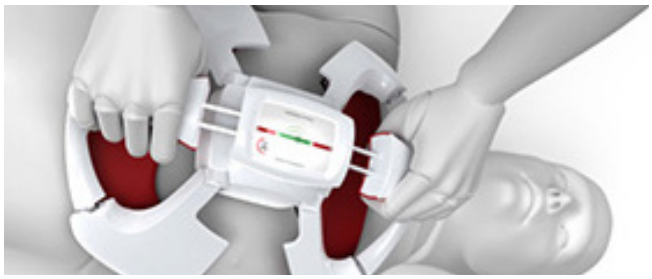
COR AED

The HeartRead was a Design Concept developed by Enzo Kocak[1] as an Honors project in 2012. This project was purely concept based without physical models, but what I found to be inspirational, was how it explored a completely alternative design for an AED, which also incorporated physical CPR-guidance for the user, making it easy to perform the CPR in the correct position

To set it up, the user pulls apart the handles which open the device from its compact form. The electrode pads are now arranged in the proper position, allowing the user to simply place the entire device on the patient's chest. After the initial shock cycle, users can administer CPR compressions by pushing down on the handles while viewing pressure feedback on the centre display screen.

This "one-step-placements" of the AED pads is something I found very interesting, as it would also minimize the number of parts, and thus hopefully lead to less confusing components. But what could be problematic here was how the semi-rigid machine body would be able to adapt to different body types and sizes. Here it would have been very interesting if the designer had made some physical mockup tests.

Weight:
Undefined
Dimensions:
Undefined

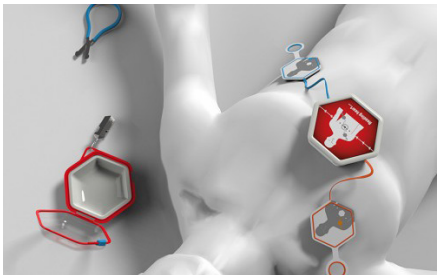


HeartRead

The HeartRead was a Design Concept developed by Mariko Higaki Iwai[2]. Though not completely refined in terms of technology, I found the usability focus of the product very interesting and inspirational. I also liked the practicality of having everything in a compact kit, which often isn't the case with current products on the market, but which makes a lot of sense in terms of efficieny in an emergency SCA situation.

Even so, something that I realized, is that this product would not work as well for women, as the female anatomy generally wouldn't work with the practical intended placement. And in that case, the product would lose one of its' main features.

Weight:
Undefined
Dimensions:
Undefined



1 https://www.behance.net/gallery/8657537/COR-AED-Automatic-External-Defibrillator
2 http://marikoproduct.com/HeartRead

PocketDefi

The PocketDefi was originally launched as a crowdsourcing product[3] in 2017 and marketed as a smaller, cheaper, portable and smartphone connected alternative to traditional AEDs, marketed towards private consumers. Unfortunately the company behind the product went bankrupt[4] before the product could be launched on the market.

Even so, there had been 3 years of development behind the product, including receiving grants from the European Comission, and it received great feedback from the crowdsourcing campaign and public media. This showed that there is an interest in the market for such a product, and also gave insights as to what is possible in terms of product technology, size and pricing.

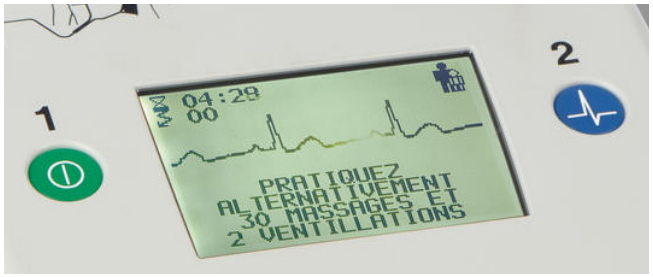
What I did find lacking was the understandability of the physical product, which as far as I could tell was so minimized that it acutally made it less intuitive. Instead, almost all of the instructions and feedback are given through connection with a smartphone. Smartphone connectivity was definitely something I saw potential in, but relying so heavily on this connection that the product itself loses a lot of its' understandability without it, is something that could exclude a lot of potential users. It could also pose a great risk in case of your smartphone running out of battery or connectivity. This was definitely an aspect I would want to improve - making the product fully understandable and functional even without smartphone connection.

Weight:
490 grams
(including batteries)
Dimensions:
50 x 80 x 100 mm

FRED easyport

The FRED easyport is marketed as the World's first pocket defibrillator, and is the smallest AED currently being sold. It is marketed towards *"doctors, paramedics, and others public service staff, high-risk patients and their family members who have been trained in early defibrillation"*[5]. Though not FDA approved, it is approved for use in countries such as Canada and Switzerland[6]. Its' small size and low weight was a useful reference of what was actually possible in terms of minimizing the AED size, but design wise I saw room for improvement, mainly in terms of organizing accessories, ergonomics and how to convey the realtime instructions - which are shown on a small LCD screen in the form of tiny text and graphics.

Weight:
490 grams
(including batteries)
Dimensions:
133 x 126 x 35 mm



3 https://www.indiegogo.com/projects/pocketdefi-dein-erster-eigener-defibrillator#/English
4 https://www.trendingtopics.at/pocketdefi-grazer-entwickler-von-mini-defibrillator-schlitterte-in-den-konkurs/
5 https://mediquest.ca/aed-demo-videos/schiller-fred-easyport-small-aed/
6 https://www.schiller.ch/ch/de/product/fred-easypor

3.15 Technical model comparison

During the development of the PocketDefi, a Bachelor thesis was written by Michael Berger[1], looking into the technical specifications of the device, and comparing it to other competitors on the market. In the chart below (extracted from the mentioned thesis), the Pocketdefi is compared to the previously mentioned Fred Easyport, Zoll AED 3 and Philips HeartStart HS1, as well as the PreveCo Life Point Pro (not FDA-approved).

In this chart, it is shown that the PocketDefi is clearly reduced in terms of size and weight. Even so, the performance is comparable to other, bigger, devices in terms of precision, effect and capacity. The only exception being the maximum amount of shocks, where the PocketDefi performs below average. In terms of shock energy, it is comparable to the Fred Easyport, but slightly below the other models in the comparison. On the other hand, it outperforms the competitors in terms of temperature resistance and price point.

Producer	liimtec	Schiller	Zoll	PreveCo	Philips
Device	*Konzept PocketDefi*	*Fred Easy-port*	*AED 3*	*Life Point Pro*	*HeartStart HS 1*
Length/Width/Height in cm	10/5/8	13,3/12,6/3,5	23,6/12,7/24,7	27/24/9,5	21/19/7,1
Weight in g	300	490	2500	1850	1500
Maximal energy in J for 1st/2nd/3rd shock	110/130/150	120/120/120	120/150/200	150/150/200	160/160/160
Maximum voltage in V	2300	2850	2250	-	1925
Maximum current in A	70	100	32	-	55
Maximum puls duration in ms	15	10	10	-	21
Maximum amount of shocks	20	45	140	100	200
Precision in %	98	99,8	95	95	95
Sensitivity VF/VT in %	99/75	96,4/-	90/75	90/75	97/81
Charging time in s	30	40	36	10	8
IP classification	68	X4	55	54	21
Max./Min. operating temperature	-10/50	0/40	0/50	0/60	0/50
Battery service life in years	5	5	5	5	4
Price in € excl. battery and electrode pads	450	1855	3690	847	1165

1 https://diglib.tugraz.at/download.php?id=5f3121938321b&location=browse

3.16 CONCLUSIONS 1.0

The main purpose of the first research phase was to learn about current AEDs and their functionality, as well as getting an understanding of the current market and which areas and aspects could be improved.

Through the desktop research, survey and interviews, it was clear that the current market is fairly limited and that most AED designs share the problematic of being physically bulky and non-ergonomic. Many of them also look very technical and do not convey an empathetic and calming message to the user. Instead, they can be interpreted as intimidating and complicated, making people more worried about using them in the wrong way, or causing harm rather than helping.

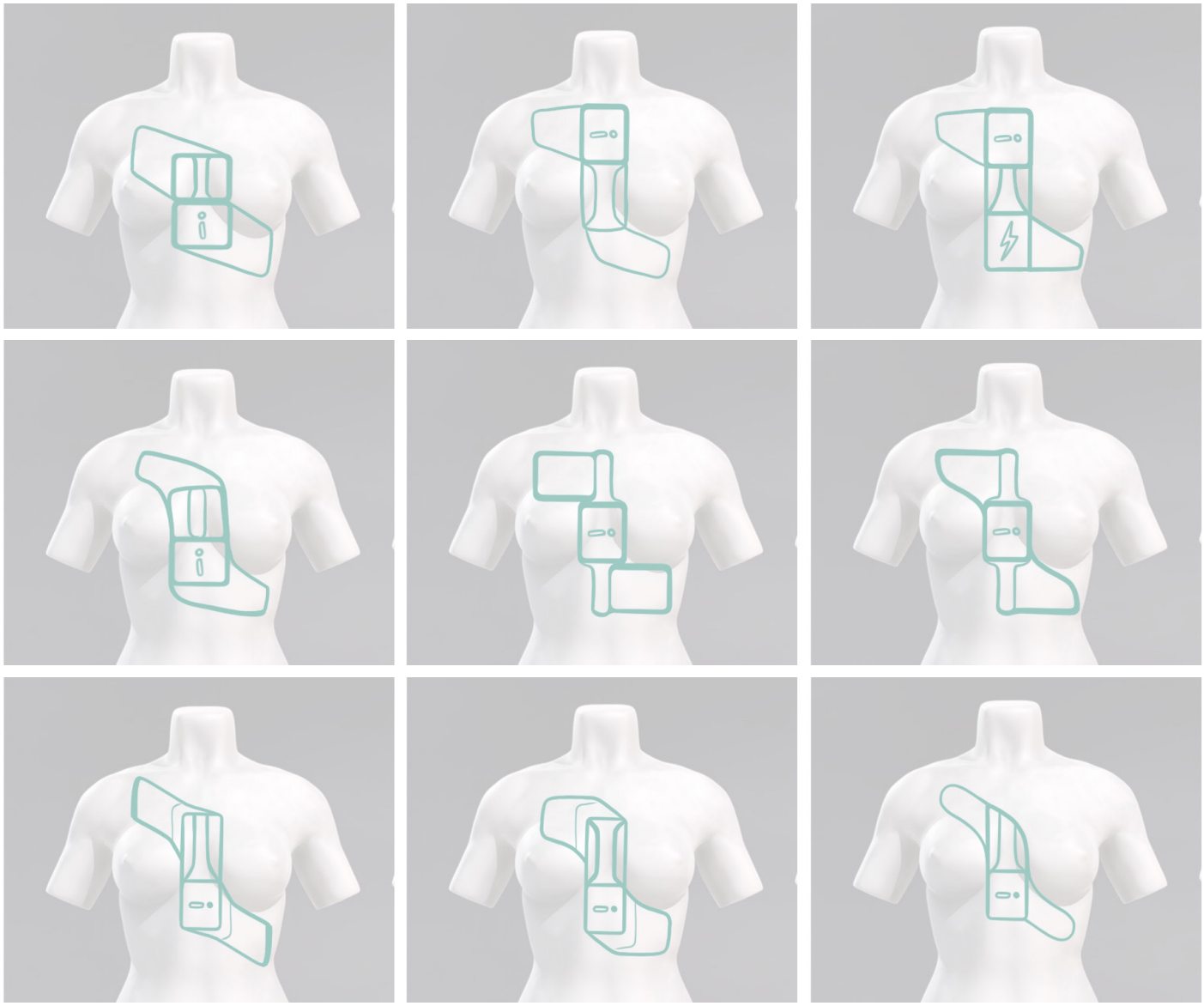
In addition, the research also showed that there are some technical things that can be improved, such as the timing of the voice instructions, organization of parts, and layout of buttons. The relay of information and instructions also turned out to be a critical aspect of usage. Based on the surveys and interviews, many are completely unaware of the actual functionality of AEDs, save from the fact that they give out electric shocks. This makes clear instructions even more crucial, something that is currently often hindered by too crowded illustrations, too many steps to follow, too much text, or too small displays on the device.

All in all, the conclusion to the first research phase was that this was a product market where the amount of products is still quite limited, and where there is still a lot of room for improvement and new ideas, making it a very interesting base for ideation.

4.0 IDEATION 1.0

The first ideation stage was an exploratory phase, which attempted to find solutions and ideas that were further away from existing products and discover which other potential roads could be taken. A phase of not yet being too constricted by technical possiblities, but rather letting ideas run a bit more freely.

4.1 Initial sketches



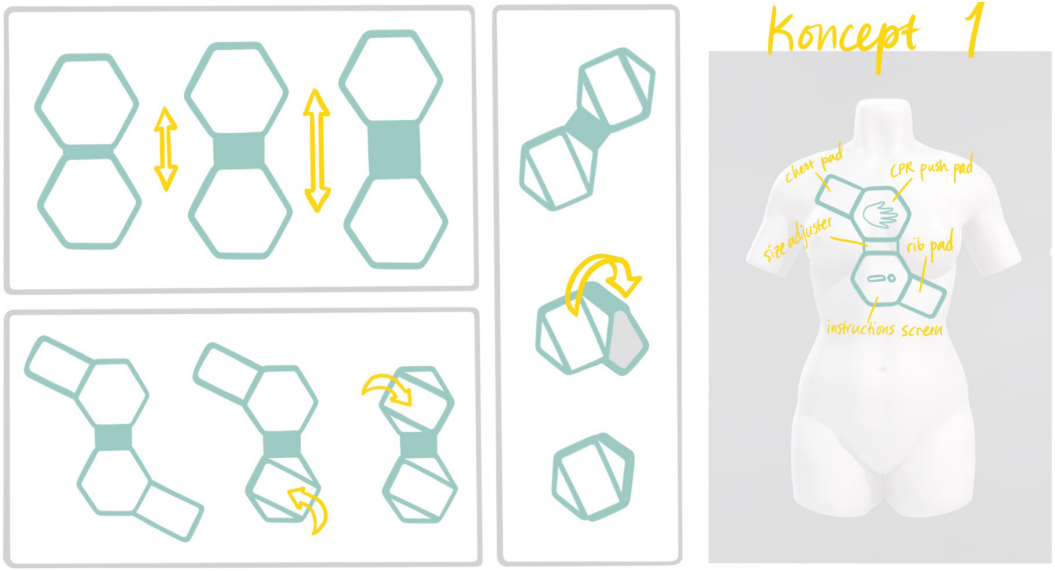
With partial inspiration from the COR AED[1], these initial sketches focused on finding a way of incorporating all main elements (device, pads, information) in one assembly, and additionally having some form of built-in physical CPR-point. Since the pressure point for CPR needs to be placed right on the chest between the ribs, the placement of the rest of the device components would be centered around this part, which was sketched as a handle. The reason for this being that a handle would be a familiar interaction element, and provide a physical grip to push down own, rather than pushing down directly on the surface of the chest.

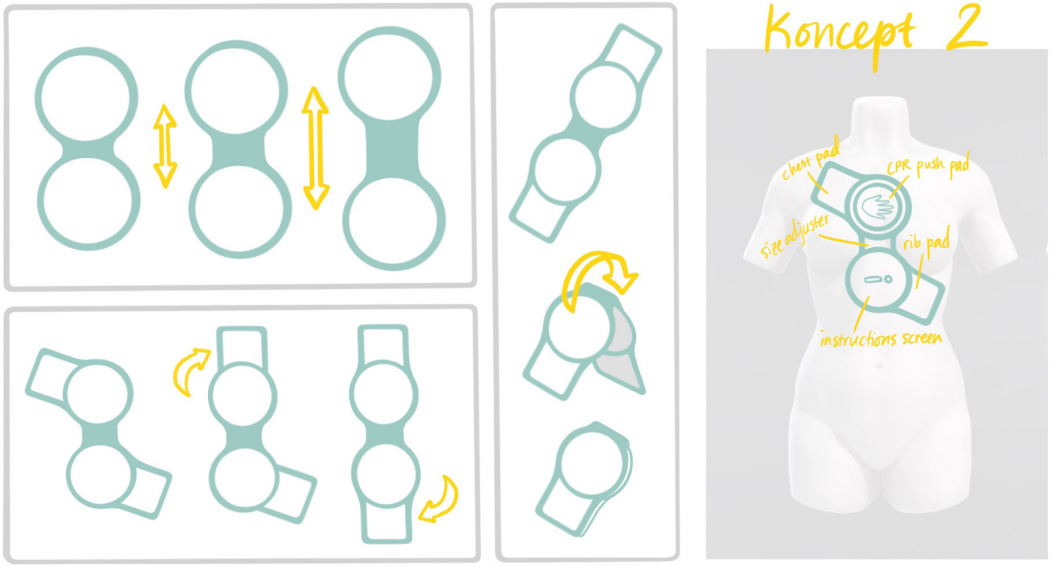
Around this handle, pads of different shapes and sizes were then placed on each top left and lower right side of the chest (seen from the front of the patient). This standard electrode pad placement is neccessary in order to send an electric current right through the heart[2]. In addition to this, all sketches incorporated some form of info screen, intended to instruct and advise the user.

At this stage, the sketches were still exploratory, and did not consider recommended electrode pad size, or the size of electrical components.

1 https://www.behance.net/gallery/8657537/COR-AED-Automatic-External-Defibrillator
2 https://www.aedusa.com/knowledge/defibrillator-pad-placement/

4.2 Initial concept ideas





The first two initial concept ideas were two slightly different variations of one and the same principle. This idea was a further development of the ideas of creating a compact device which simplified correct placement of electrode pads and CPR location, as well as reducing or even eliminating the amount of loose parts.

Both of these ideas were based on a fold or fold-and-turn motion, where the user unpacks the device similarly to a package, before placing the whole device, unfolded, onto the torso/chest of the patient.

In contrast to the previous sketches, the CPR point was changed to a button-like construction, rather than the previous handle, since it was realized that a handle would not unambiguously convey a pushing motion, but rather could be confused as intended for pulling. For a pushing motion, a button would semantically give a clearer instruction to the user, while still providing a mechanical and physical point for the CPR action.

As for the shapes, they were based on the space available around the chest. As other AED concepts working with on-chest placements were not optimized for a female anatomy with possibly bigger chest, I wanted to use the female torso as a guideline for which shapes could be possible. With the surface area needed to incorporate the desired functions (electrode pads, CPR “button” big enough to fit the palm of a hand, and as big of a screen as possible), some combination of circular pads were the resulting shape. After evaluating these two versions with my mentor, supervisor and classmates, the initial opinion was that the rounded version better conveyed the empathic form language I set out to achieve.

5.0 RESEARCH 2.0

After starting the first ideation phase, it became clear that the scope of the project was still too wide, and the target group too undefined. There were many ideas for improvements, but it was not clear which specific user groups would benefit the most from these new ideas.

In order to target the end user in a more focused way, I decided to narrow down the target group to the non-first-responders that would have the most interaction with AEDs: users or relatives of users who were in a risk group for experiencing a Sudden Cardiac Arrest. Since these are the groups who would have the highest risk of having to use AEDs during their lifetime, and would also be the groups who would benefit the most from owning an AED for personal use, I found that their needs and requirements would be more rewarding to define and focus on.

After reaching this decision, I continued into Research phase 2.0. While the first phase focused more on gathering general SCA and AED knowledge, this second phase took a closer look at the lives of people in this newly narrowed down target group, and their needs and preferences for personal AEDs.

5.1 New brief

With the findings from the first research phase and ideation, the project brief was adjusted. The initial idea was to design an AED mainly targeted towards completely inexperienced users, but the research showed that this group was too undefined, and the main helping factor was taking AED courses, rather than changing the AEDs themselves.

On the other hand, the groups which need AEDs for personal use, turned out to be the groups with needs strongly connected to the improvement of AED devices - making this a more relevant target group. With this in mind, the brief was changed. The geographical scope was also narrowed down to Sweden, mainly due to the limitations of the ongoing pandemic.

Design a more portable Automated External Defibrillator which targets existing pain points in AEDs targeted towards personal use

5.2 New target group

- Previous experience of Sudden Cardiac Arrest
- In a risk group for Sudden Cardiac Arrest
- Relatives of someone in a risk group for Sudden Cardiac Arrest
- Living in Sweden

5.3 Survey II

With the updated brief, a new survey was made in order to identify the specfic pain points of the defined target group. While the previous survey focused more on general understandability and experience, the second survey targeted more in-depth topics such as purchase considerations and current/planned behavioral patterns of the intended target group.

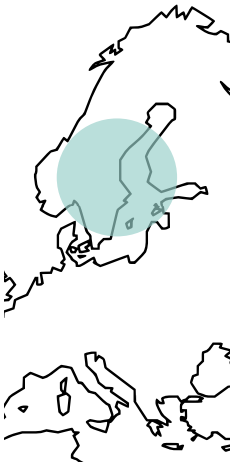
The survey respondents were sourced from three closed facebook groups moderated by the Swedish organisation Hjärt-Lungfonden. These groups were specifically aimed at survivors and close relatives of victims of SCA and heart attacks, as well as a group for women with heart problems, since I was interested in how AEDs could be more inclusive towards the female body.

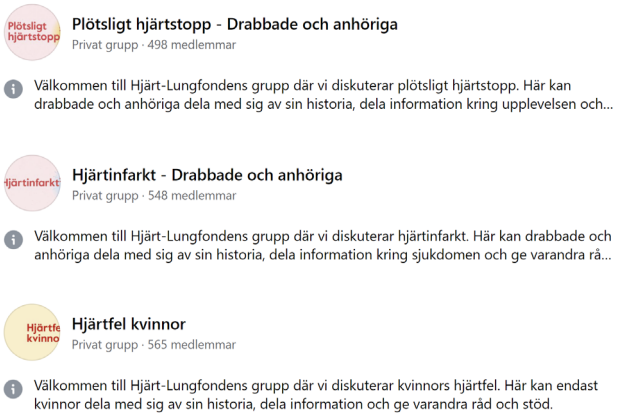
25 participants

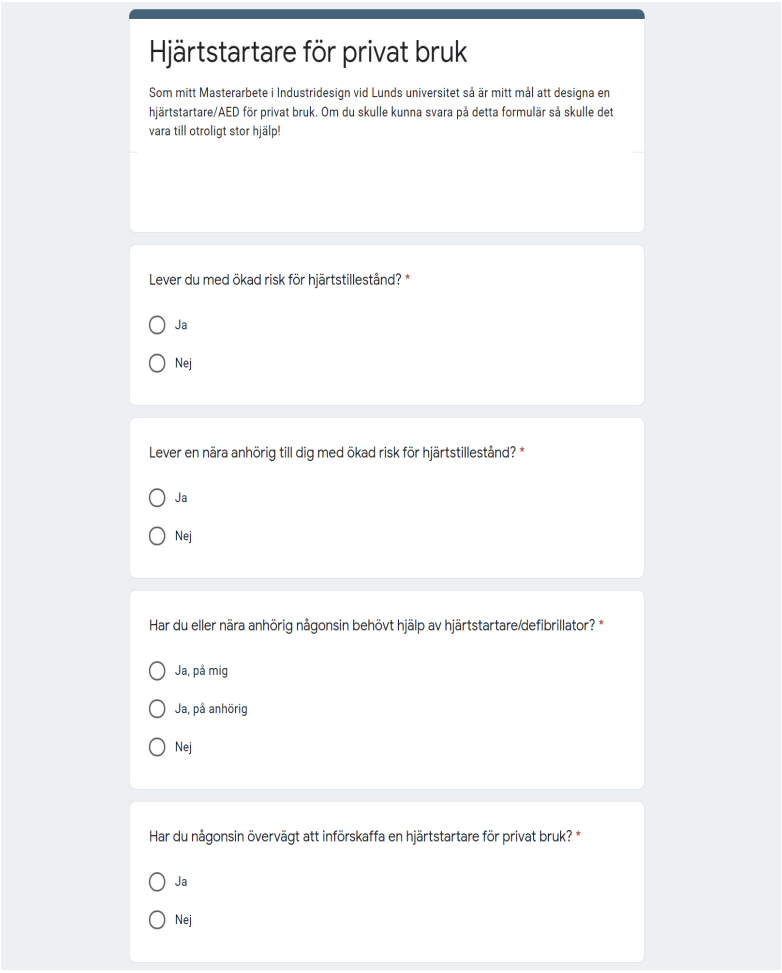
Sweden

Risk groups

Experience of SCA







Online survey, Google forms

23 questions

Purchase considerations

Personal preferences

Needs and expectations

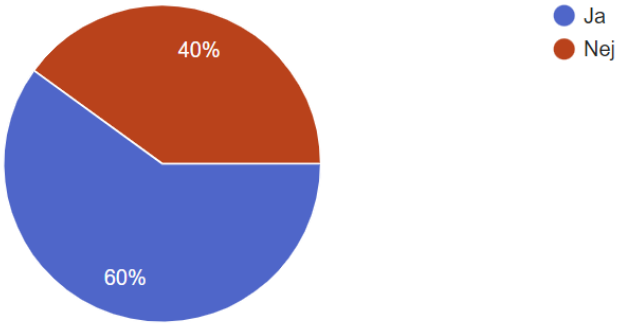
Personal experience

The first questions of the survey looked at how the respondants fit into the target group. All 25 respondents fit into one or more of the following groups

- In risk group for Cardiac Arrest
- Close relative of someone in risk group for Cardiac Arrest
- Personal (or close relative of someone with) experience of having needed an AED

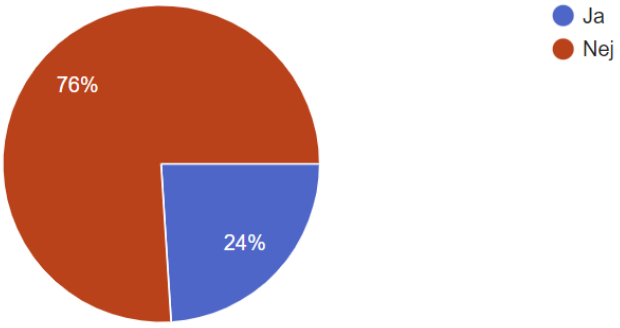
Are you living with an increased risk of experiencing Sudden Cardiac Arrest?

25 responses



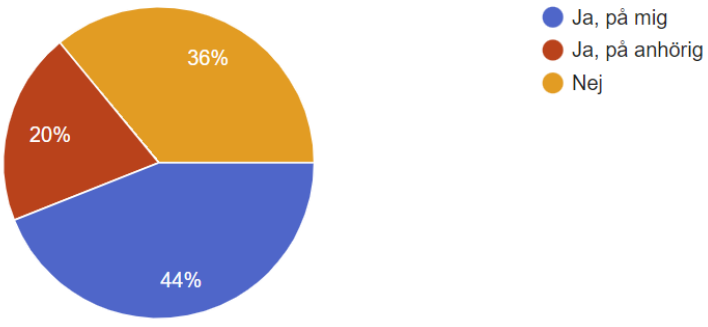
Are you a close relative of anyone living with an increased risk of experiencing Sudden Cardiac Arrest?

25 responses



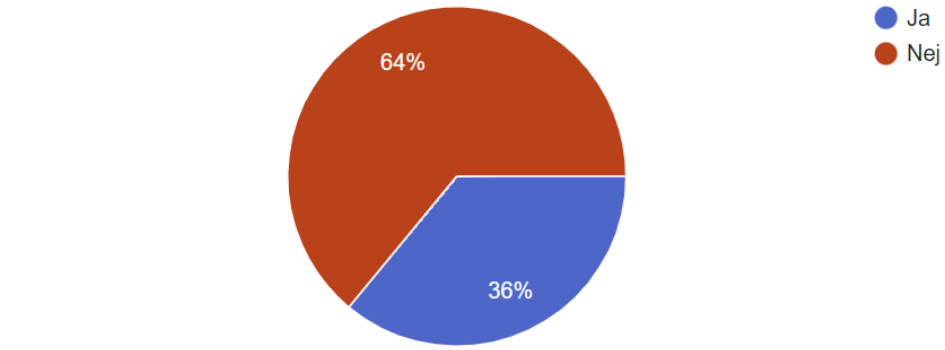
Did you or a close relative ever have a heartstarter used on you/them?

25 responses



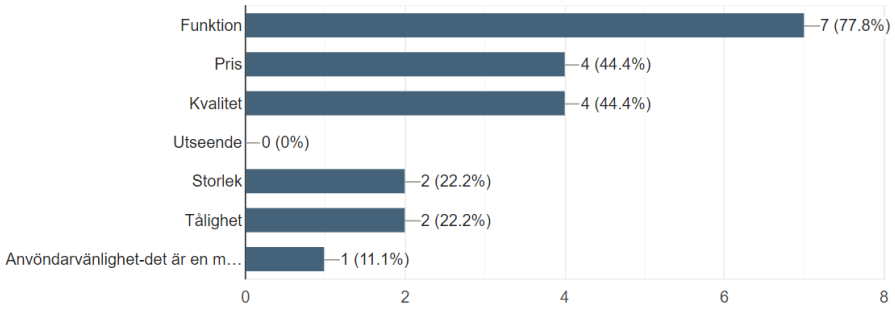
Did you ever consider purchasing a heartstarter for personal use?

25 responses



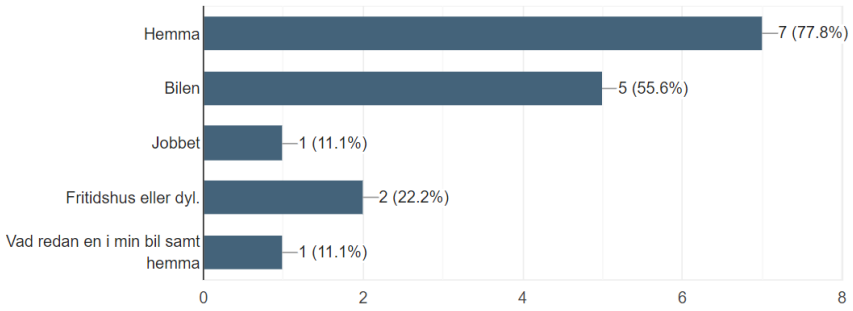
Which of these factors were the most important to you when you considered purchasing a heartstarter?

9 responses



Where did you plan to store your heartstarter?

9 responses



Previous purchase considerations

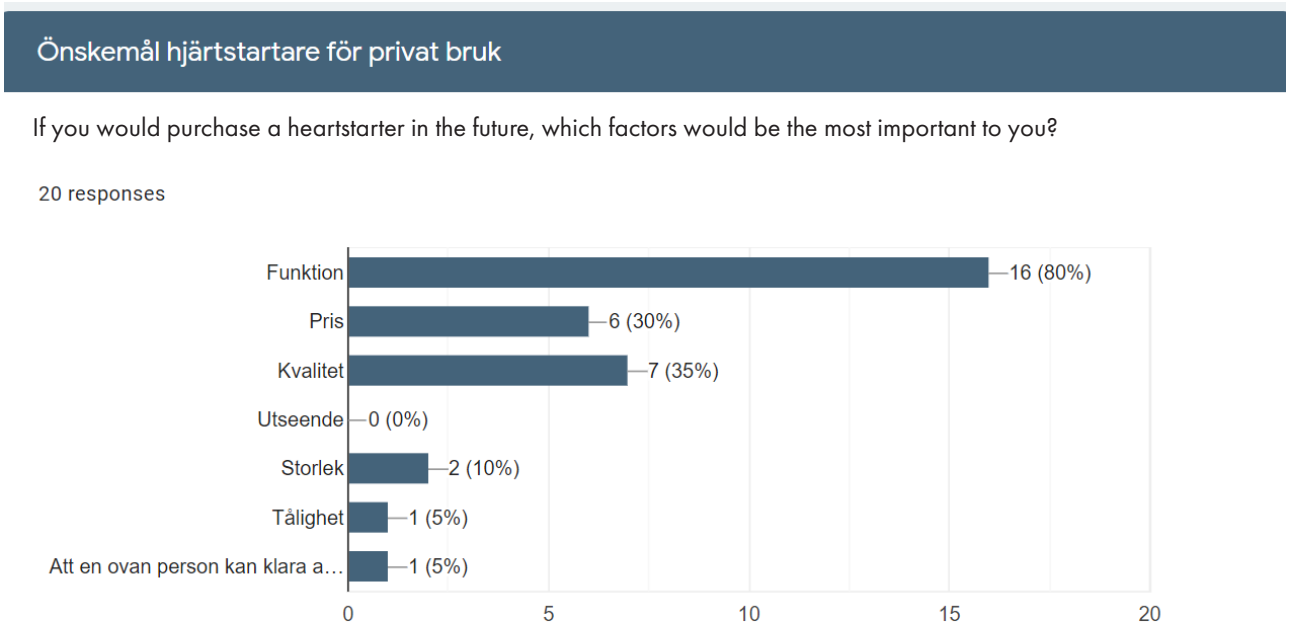
Following the target group criteria, the survey looked into the experience of the respondants who had previously considered purchasing an AED for personal use (36%), and which factors were the most important to them during this process. With 9 respondants, this was a more qualititative look into the purchasing journey, and the answers showed that functionality was the most important factor for the users, while looks were deemed the least important. Meanwhile price and quality were also important factors.

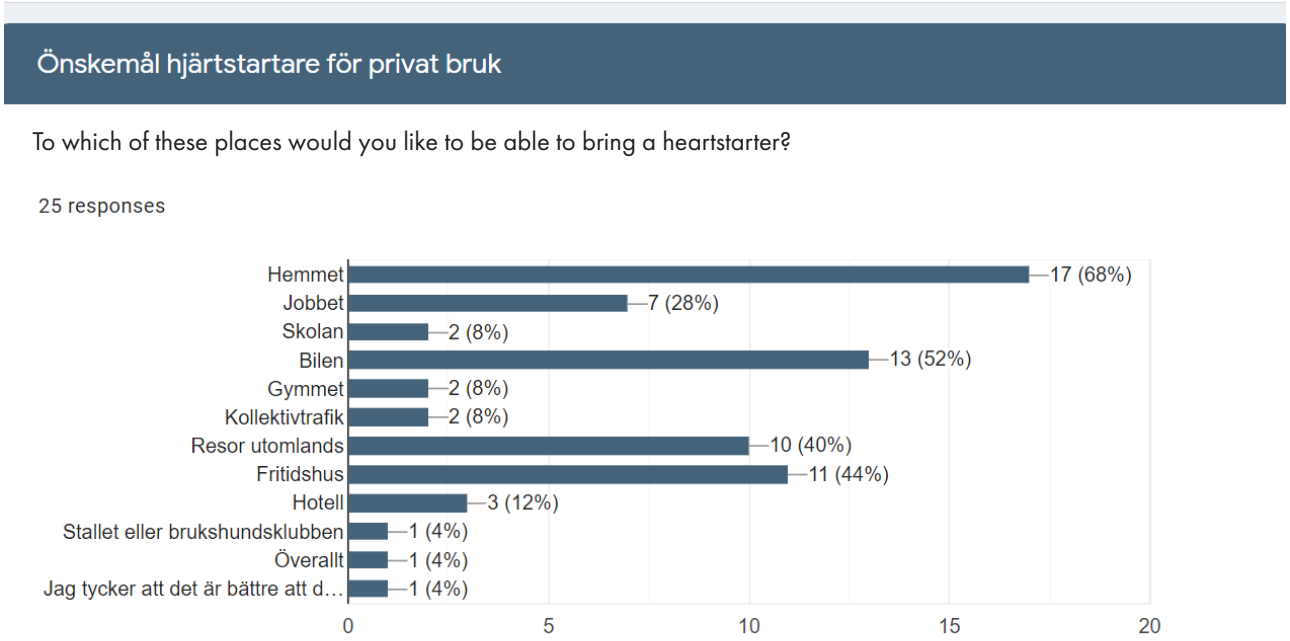
As for everyday storage, most said they would store the AED at home or in the car, giving me an insight into which kinds of environments would need to be considered and adapted to while designing the AED.

Future purchase considerations

In the next part of the survey, all of the respondents were asked about wishes for future purchases. Here the result concerning priorities was very similar to that of the previous question, with functionality, price and quality again being the most important purchase consideration factors.

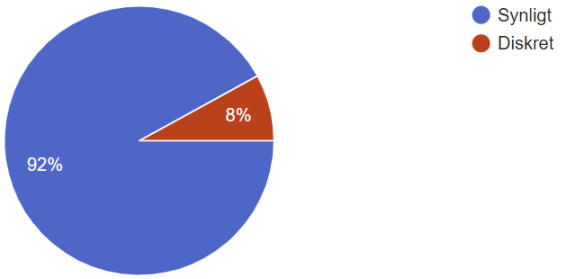
As for wishes for portability, once again the home and car were the most popular choices, but being able to travel with the AED abroad or bringing it to a vacation house or to work was also rated highly, showing that there was a desire for portability and higher flexibility of where to use the device.





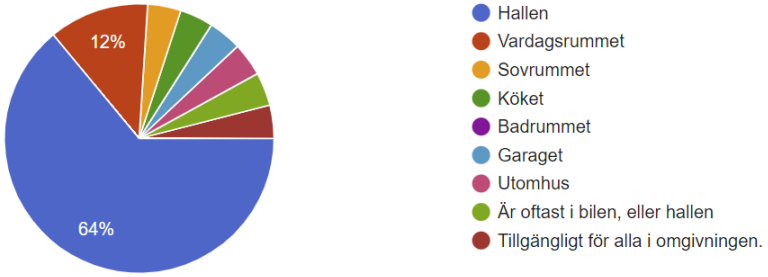
Would you prefer to store a personal heartstarter visibly or discreetly? For ex. at home

25 responses



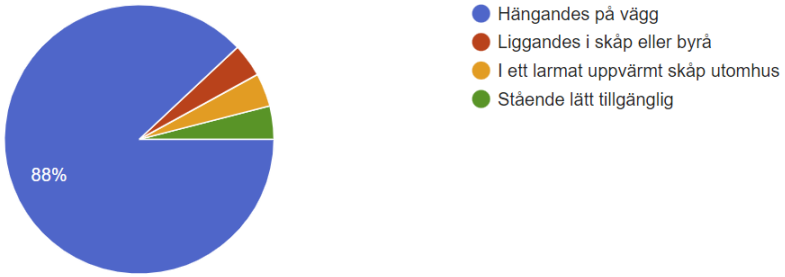
Where in your home would you prefer to store your heartstarter?

25 responses



How would you prefer to place your heartstarter?

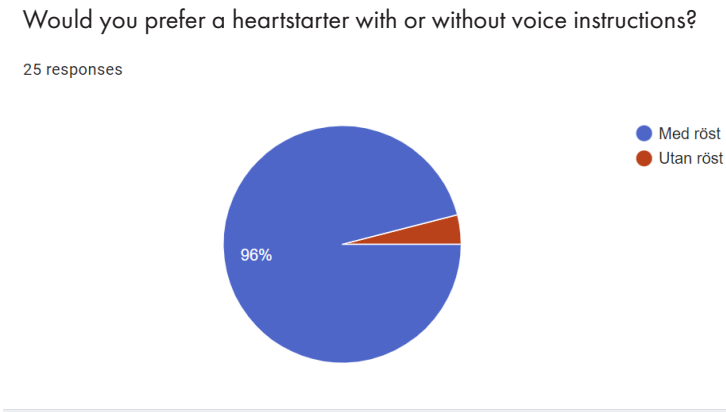
25 responses

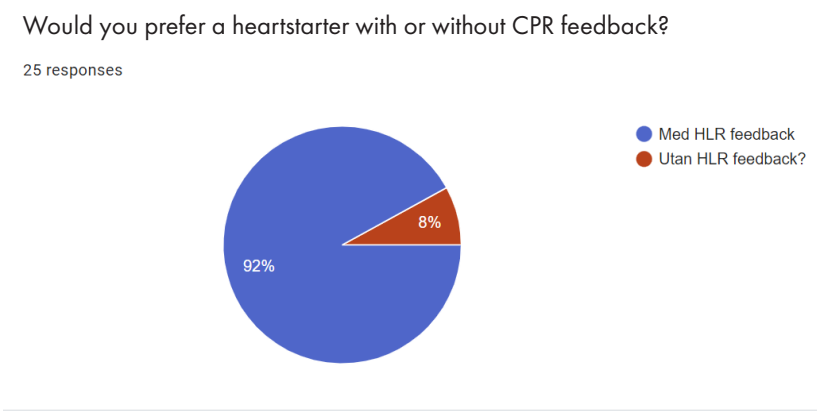


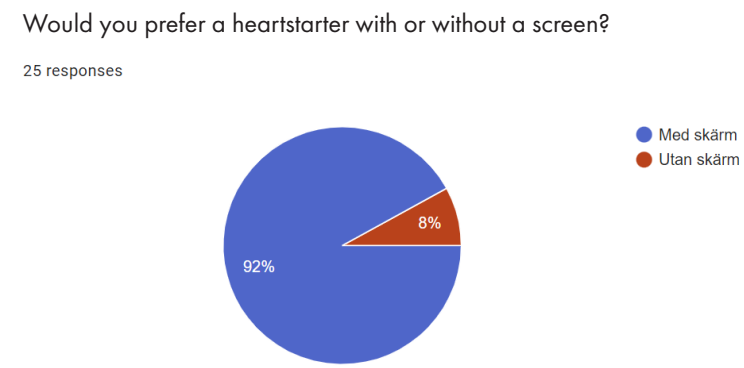
Color and Storage

Following the questions about purchase considerations, the survey continued by doing some initial CMF exploration - asking about desired colors and whether the respondants preferred the device to be discreet or to stand out. Pictured above are some questions about desired storage and placement in the home.

The answers to this part of ths survey gave useful insights into possible sizes and features that the AED would have to have in order to be stored in and used in the ways desired by the target group respondents.







Desired features

Next, the survey looked into which features the respondents preferred the device to have. Here, a majority of respondents answered that they preferred the device to have both voice instructions, CPR feedback and a screen, in contrast to the insights in Research phase 1.0, which showed that voice instructions were crucial, while CPR feedback and screens where “nice-to-haves” but not essential. This was especially true in the case of screens, which were often deemed to be less useful.

Towards the end, the respondents were also asked to freely suggest which other wishes or features they wanted in an AED.

Here, several respondents pointed out that spare batteries can be expensive or difficult to find, and also wished for a reminder when batteries or electrodes needed replacing, since it can be hard to remember. Other suggestions included:

- Reminder to call emergency services
- Possibility of changing language
- Optional CPR guidance
- Extremely easy to handle
- Reasonable price
- Wifi connection
- Able to save usage data

5.4 Survey II results

The second survey gave a deeper understanding of the narrowed down target group and zeroed in on some of their specific needs and desires. With the help of these answers the project was given a more targeted direction and more defined problem areas, making it easier to start to envision what kind of product should be designed for the project.

- Functionality is the most important deciding factor when choosing between different AED models
- High prices were the most cited reason for deciding against buying an AED
- The main storage locations are at home and in the car
- The Philips HS1 was the most commonly considered model among the respondents
- An extended wish for portability (travels abroad, workplace, vacation house) was identified
- For everyday transport in handbags/backpacks, a more discreet device look was preferred
- At home, an AED would most likely be placed hanging in the hallway or living room
- An annual maintenance interval is the most accepted
- A majority of respondents wanted an AED to have voice instructions, HLR feedback and a screen
- Batteries and spare parts can be expensive to replace, and need reminders for when to be exchanged
- Digital connection can give an added value e.g. in form of storing usage data

5.5 Interviews II

As a last question in Survey II, the respondents were asked if they were willing to be contacted for participation in more in-depth interviews. Several respondents volunteered for this, and I got to learn more about their personal experiences and situations, in order to learn more about which kinds of needs they might have. These interviews were very insightful, and it was truly humbling getting to hear about experiences and situations that were so personal and life-changing. The four respondents I ended up interviewing all had very different experiences and connections with SCA and AEDs, making it possible to get a very wide range of insights from these interviews.

Interview 1: Former paramedic with SCA experience

The first interview was with Gert Thelin, a former paramedic with 43 years of working experience in Sweden and Norway. With his long experience he still remembered the 70s when portable AEDs were first introduced for ambulance use and had been able to follow the AED developments and improvements ever since, up until 2018 when he retired.

Apart from having extensive experience of using AEDs on patients, he also personally experienced a Sudden cardiac arrest in 2015 while stepping out of a train. In his case bystanders started giving CPR, followed by being defibrillated 4 times by ambulance personnel who arrived at the scene after only 3 minutes.

Personal situation

- Got a PCI and a couple of stents at the hospital after his SCA
- No secondary diseases after the SCA, which is rare
- Got an ICD (implantable cardioverter-defibrillator - *a small battery-powered defibrillator implant*) implanted during the week following the SCA
- Has a vacation house 100 km from the closest ambulance, so has considered purchasing a personal AED both for himself and for use by the surrounding neighbours since an ambulance would take too long.

Interview 2: Personal SCA experience

The second interviewee was Kicki Gustafsson, who experienced a SCA in 2019. At the time she was all alone at home, but shortly after her husband came home and found her lifeless. He then managed to perform CPR alone for 20 minutes until the ambulance finally arrived and could take over. The ambulance personnel then went on to use a LUCAS chest compression device (example pictured below) on her. In total, her cardiac arrest lasted for 40 minutes and it is considered a miracle that she survived with no major impairments.

Personal situation

- Minor cognitive impairments after SCA
- No memories of the situation from when it happened
- Does not have any implants or stents in place
- Does not currently own an AED
- Would prefer being able to store an AED in her purse

Interview 3: Young daughter in risk group

The third interview was with Isabella Andersson, mother to 4-year old Lilly, who has Brugada Syndrome; a rare, but potentially life-threatening heart rhythm disorder which leads to an increased risk of having irregular heart rhythm.

At age 2, Lilly started having unexplainable fainting episodes, and got a Reveal Linq heart rhythm monitor implanted, which showed that she regularly had cardiac arrrests lasting as long as 19 seconds. Because of this she got an AED from the hospital (pictured below), since the doctors did not want to implant a pacemaker or ICD.

Personal situation

- Got a Philips HS1 from the hospital
- The AED weighs 2kg and is extremely cumbersome to transport
- Lilly eats heart medication but still has to bring the AED with her to kindergarten every day
- The AED is usually placed underneath her younger brother's stroller on the way to kindergarten, but Isabella worries about how Lilly will be able bring it by herself once she starts school

Interview 4: Nurse who owns personal AEDs

The last interview was with Johan Månsson Christell, a nurse who also owns 2 personal AEDs (pictured below) of which he stores one at home and one in the car. Johan does not himself have any experience with SCA, but is a volounteer within Svenska Livräddarsällskapet, an Swedish volunteer organisation dedicated to assisting regular hospital resources in case of emergencies when the nearest ambulance might be too far away. With his involvement in this organization and experience with different brands of AEDs, he was able to share some insights into owning a personal AED.

Personal situation

- Owns a Philips HS1 and a Physio-Control Lifepak CR2
- Many personal AEDs on the market have too short running times, needing replacement batteries too often
- Batteries and electrodes are often very expensive to replace
- It would be great if AEDs could be connected for software updates directly from the manufacturer
- Wifi connected AEDs enable the owner to receive reminders when electrodes or batteries need to be replaced

5.6 Current usage flow

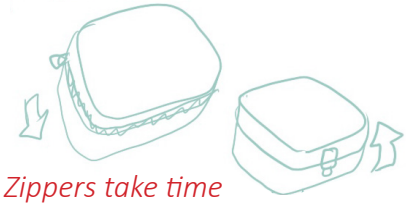
1. Check patient
Consciousness, breathing

2. Call emergency service
Ask for closest AED

3. Locate AED
Bring to patient

If alone, can not leave patient to fetch AED

4. Open AED case



Zippers take time

Small closures hard to pinpoint under stress. Too thin/brittle = easy to accidentally break

5. Locate instructions and accessories

Confusing instructions

Several compartments, many accessories Overwhelming

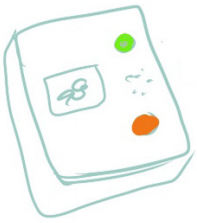
6. Open/cut open clothes

7. Read instructions

Too much text or not enough instructions. No CPR info

7. Turn on AED

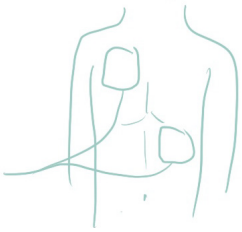
8. Follow image instructions on screen



Still images on screen show the same pictures as on pamphlet, double information

9. Follow voice instructions

10. Place electrode pads
Onto right chest
Underneath left chest



11. Keep clear of patient
Analyzing heart rhythm

12. If shock is needed:
Press shock button

Many inexperienced users unaware that shock can not be given if not needed

13. Shock is administered

14. Give CPR
Voice instructions for rhythm

15. Repeat step 11-14 until consciousness is regained

37

5.7 Function Analysis

Function		Classification	Comment
Illustrate	Usage		
Animate	Usage		
Instruct	Usage		With voice
Administer	Electric shock		
Analyze	Heart rhytm		
Register	User flow		
Instruct	CPR		
Provide	Feedback		Real-time
Be	Portable		
Simplify	Positioning		Of pads
Prevent	Misplacement		Of pads
Provide	CPR point		
Be	Adaptable		Adult+pedriatric attachments
Minimize	Weight		
Eliminate	Misusage		
Be	Robust		
Conduct	Self-checks		
Simplify	Maintenance		Battery/component replacement
Attract	Attention		
Minimize	Interaction steps		
Confirm	Actions		That are made
Simplify	Usage		
Evoke	Trust		
Confirm	Functionality		Battery/overall status
Be	Clear		How to use
Eliminate	Confusion		
Provide	Storage		Of all components in the kit
Provide	Cues		Interaction
Be	Intuitive		How to use
Be	Effective		
Minimize	Components		Number of
Increase	Size		Of buttons/illustrations
Maximize	Portability		
Be	Quick to open		
Minimize	Weight		
Maximize	Comfort		User
Maximize	Comfort		Patient
Provide	Stability		Placing positions
Improve	Usability		Handle
Adjust	Joule		Depending on pad attachment

With the knowledge and information from the two research phases, a function analysis was compiled in order to get an overview of the importance of different desired device functions. Many of these functions already exist in current AEDs, but there were also several that were based on suggested improvement needs and pain points in current models.

critical | good to have | lower prio

5.8 CONCLUSIONS 2.0

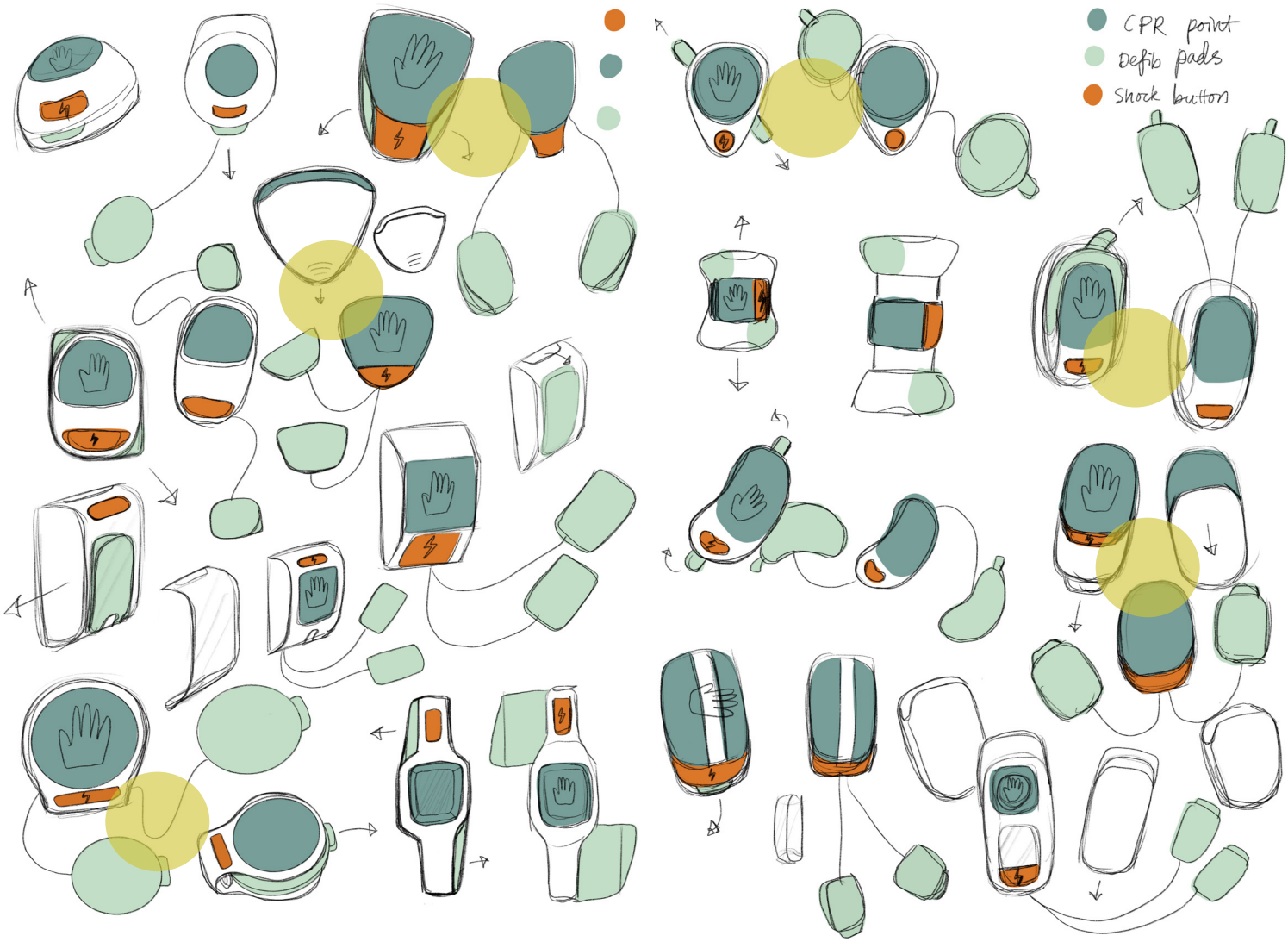
Continuing the research and narrowing down both the target group and project scope enabled me to focus more clearly, and establishing the base for a more realistic and thought-through design, with tangible connections to real-life needs and issues.

While the first research phase gave a good general idea of AED functionality and market position, the second research phase was crucial in order to figure out which improvements and features I wanted to focus on in this specific project.

6.0 IDEATION 2.0

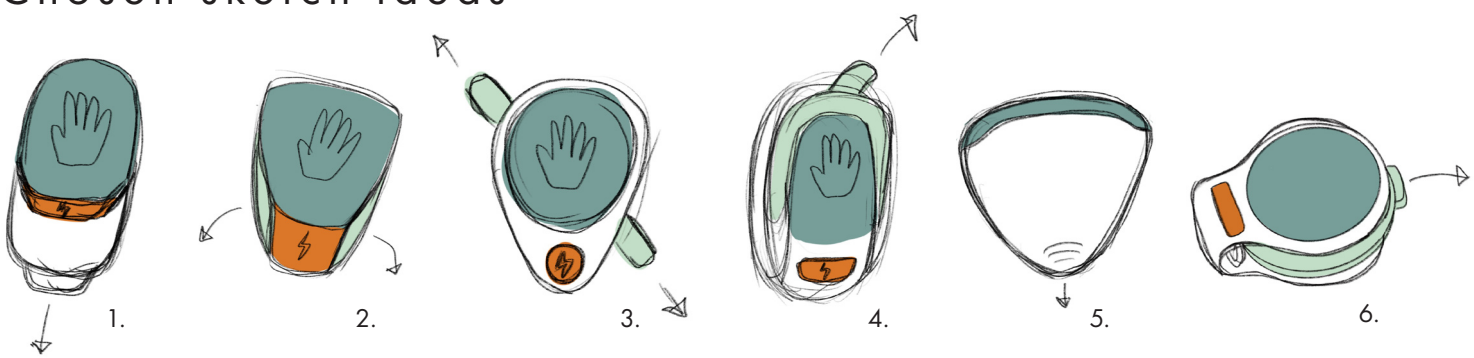
In this second ideation phase, there was a stronger focus on form and functionality, exploring which directions had the potential for being tested as physical models. This phase also further explored different electrode pad sizes and storage solutions.

6.1 Initial sketches



With focus on electrode pad storage and device shape, these loose sketches became the base for the continued ideation. Together with the interview group, a “dot exercise” was done, where the participants got 3 dots each, with which they were asked to mark their favourite sketch ideas. At this stage, the ideation was still done quantitatively and the goal was to intuitively select a couple of concepts to further detail in 3D, in order to be able to discuss and evaluate the concepts on a more relevant level. Even early on, the main goals and functions were clearly considered, but as AEDs are very three-dimensional devices with many factors to consider, these types of loose sketches could only give a vague indication of the concepts.

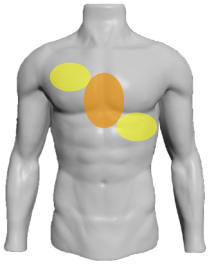
Chosen sketch ideas



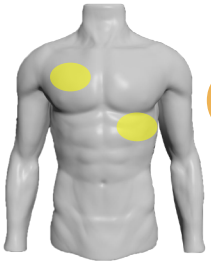
Device placement options

defibrillator

pads

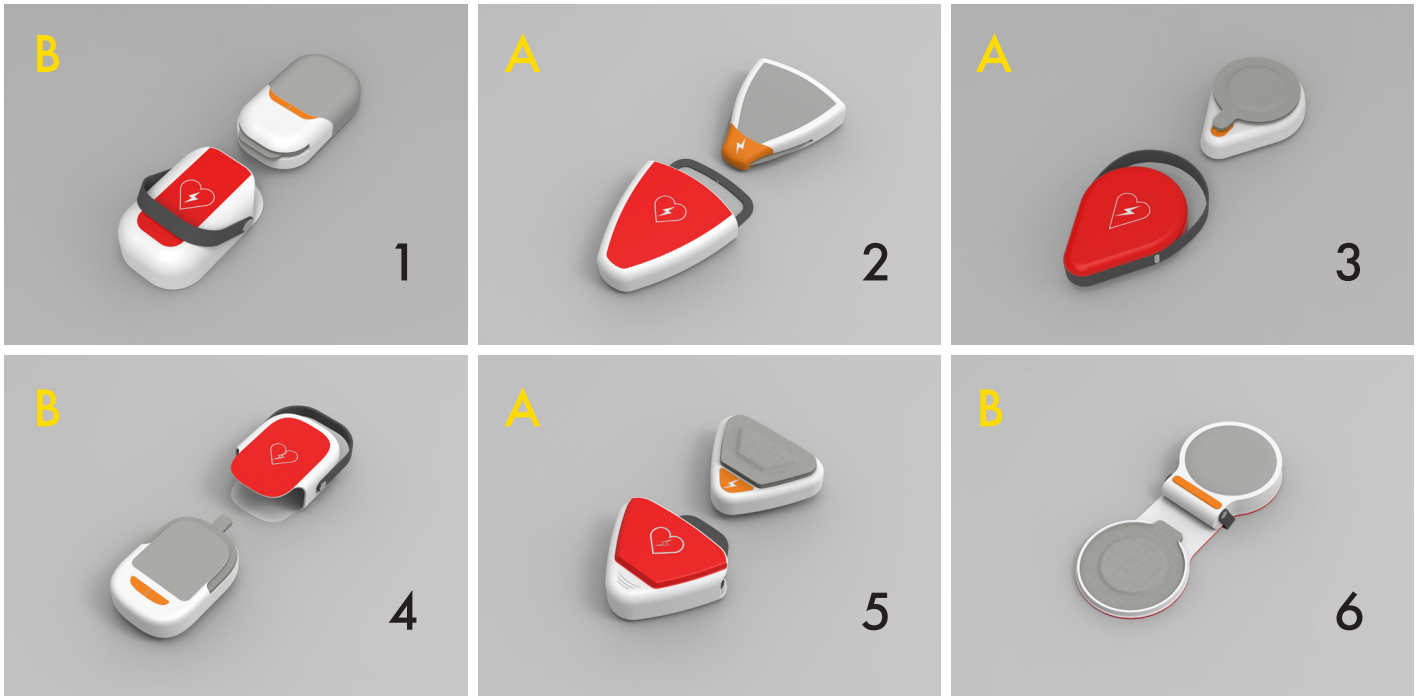


PLACEMENT A
No screen + CPR compression pad right on chest



PLACEMENT B
Screen + CPR sensors in electrode pads

6.2 Quantitative CAD exploration



Based on the chosen sketch ideas, six CAD models were made. This made it possible to define the volumes of the ideas and offer a better view of the details and components. The main goals of these designs were to explore a wide range of shapes and functionality, in order to zero in on desirable or problematic features. For example, both static and turnable handles were shown, closed and semi-open cases, wide or narrow handles, case openings facing both up and down, flatter and thicker devices, external and built-in cases, device placement in relation to the body, as well as different shock button shapes and sizes.

As mentioned, electrode pad storage was also a big focus - and these concepts offered several solutions to how this storage could be solved. Since the inspiration sketches were very basic, a lot of the form and detail development was done during the actual modeling. Half of the ideas had the electrode pad storage built into the device itself (1, 2, 4), while the others (3, 5, 6) had storage built into the case.

Most commonly, electrode pads for AEDs are in the shapes of rounded rectangles or ovals. Here, other shapes were explored as well, resulting in both the traditional rounded rectangle, but also pseudo-triangular, square, and circular shaped electrode pads. With the goal of minimizing the size of the AED device, the size and shape of the electrode pads were generally used as a guideline for the size and shape of the devices themselves, since the pads ideally would not need to be bent during storage/transport. The idea was also to maximize the electrode pad size/surface in relation to device size, as studies show that larger electrode pads (12x12cm)[1] lead to better results than smaller ones.

1 https://www.ajconline.org/article/0002-9149(89)90757-1/pdf#relatedArticles

6.3 Concept overview

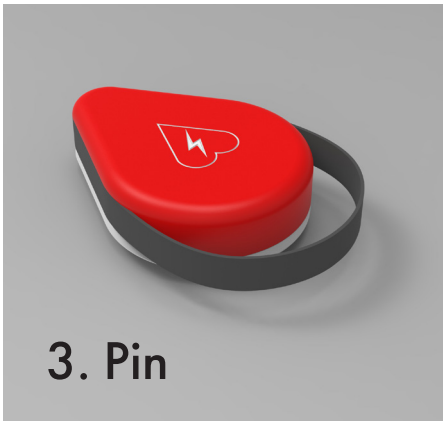
Attribute / Feature	1	2	3	4	5	6
Static handle		■		■		
Turnable handle	▒		▒		▒	▒
Bottom-facing case opening				■		■
Top-facing case opening	▒	▒			▒	
Closed case			■			■
Semi-open case	▒	▒		▒	▒	
Wide handle	■	■	■	■		
Narrow handle					▒	▒
Large electrode pads			■	■		■
Intermediate electrode pads	▒				▒	
Smaller electrode pads		■				
Compact shock button		▒	▒		▒	
Long shock button	■			■		■
Rectangular device shape	▒			▒		
Triangular device shape		■	■		■	
Circular device shape			▒			▒
Foldable case						■
Built-in case						▒
Placement A (physical CPR point)		■	■		■	
Placement B (CPR sensor)	▒			▒		▒
No screen		■	■		■	
Screen	▒		▒	▒		▒
Pad storage in device	■	■		■		
Pad storage in case			▒		▒	▒
Flat device		■	■			■
Thick device	▒					

6.4 Concept evaluation

Out of the six CAD models, the selection was narrowed down to three for the first mockup tests. The selection was made in discussion with the interview group, and based on a ranking of the attributes/features shown on the previous page. Below are the five highest ranked features.

Attribute / Feature	Votes
Pad storage in case	4
Placement B (CPR sensor)	4
Closed case	4
Bottom-facing case opening	3
Turnable handle	3

Based on this voting, as well as general interest and preferences of the participants, concept 3, 4 and 6 were chosen for mockup testing. Apart from having many of the desired attributes, the main deciding factor of the participants were that these models clearly separated themselves from traditional AED models which are currently on the market. The fact that these models clearly stood apart from those AED models in terms of device shape, electrode pad storage, case design and perceived practicality, was what drew the interest of the participants and made them believe the designs had the potential of fulfilling the needs which are not met by models sold on the market today.

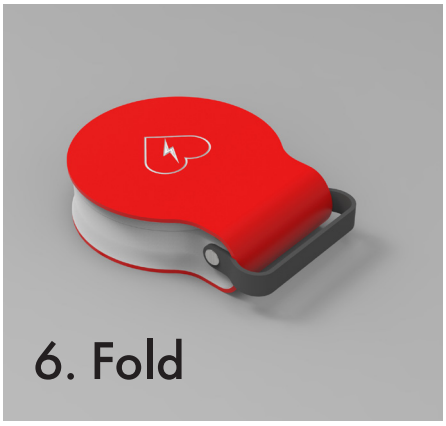


With a shape reminiscent of a location pin, this design has a shape that enables it to fit right on the chest, with the aim of offering a physical pressing point for CPR.

The lid covers the full front of the device and is attached magnetically, for quick and hassle-free removal. Once the lid is removed, the electrode pads are found placed on top of the device.

For quick access, this design has a semi-open case with a bottom-facing opening, enabling the user to hold the handle during transport and then quickly pull the attached device out with the other hand in one motion.

As the user does so, their attention is directed at the tabs of the electrode pads, which are stored just behind the screen for easy, integrated storage.



With a built-in case, this design focuses on minimizing the number of components the user has to deal with during an emergency situation.

When opened, the case opens up wide, and gives access to the electrode pads, with their dedicated storage located on the inside of the lid, offering all essential components laid out at a glance, with direct access.

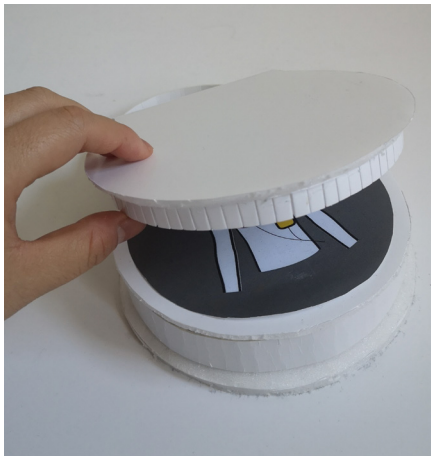
7.0 USER TESTS

To get a better understanding of how the new ideas and features would impact the user experience, user tests were conducted with four participants. Due to the COVID-19 pandemic, it was not possible to conduct these user tests with the previous interview participants from the target group, since in-person observations and dialogue was an important part of this step. Instead, four people from Lund were chosen; two with previous AED knowledge, and two who lacked any experience. The age span was 20-28 years old, with even gender division and nationalities being Swedish, Portuguese and Italian.

With this limited but divided selection, the aim was to gauge the intiuitiveness and general understandability of the concept ideas, as well as identifying any pain points.

7.1 Cardboard mockups

The three cardboard mockups were made by hand and based on the shape and proportions of the CAD models. As for dimensions, the PocketDefi[1] and FRED EasyPort[2] were used as a references for what was the minimum possible size, together with considerations and tests in terms of handle width and electrode pad size.





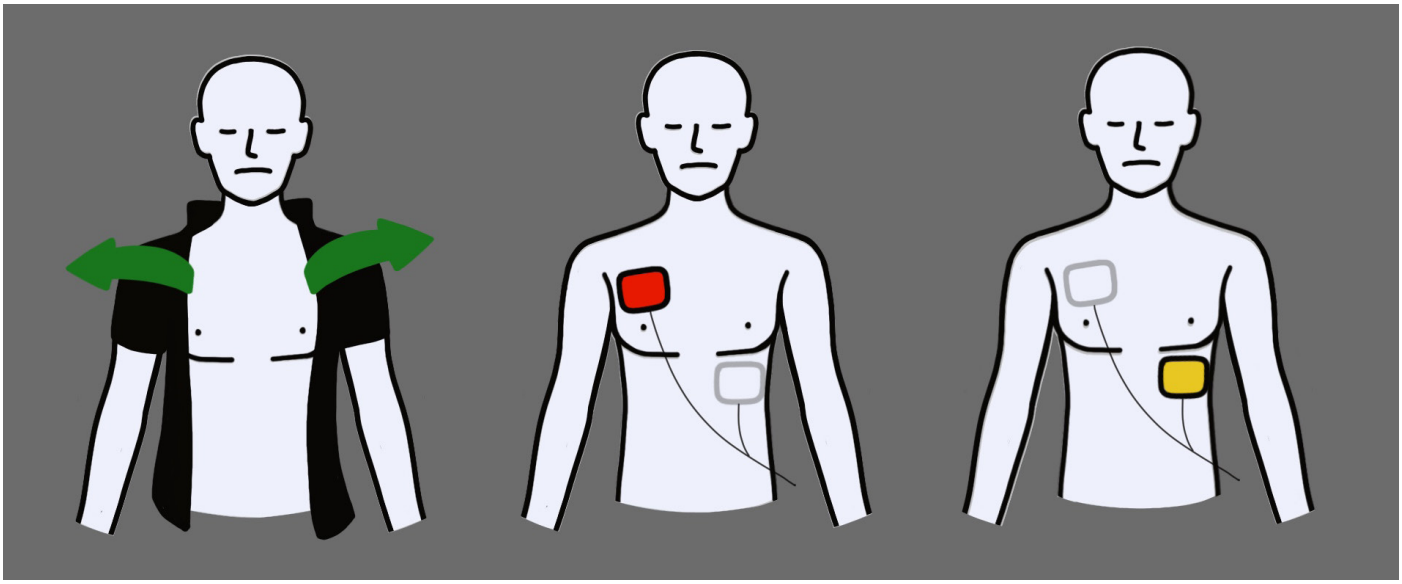

1 https://www.indiegogo.com/projects/pocketdefi-dein-erster-eigener-defibrillator#/
2 https://www.aedexpert.co.uk/schiller-fred-easyport.html

7.2 Analogue testing features

Apart from offering a realistic sense of volume and shape, the main goal of the mockups were to test functionality and user interaction. In order to emulate this experience with basic analogue models, certain features were added to the device mockups.

Weight: To give the mockups a realistic weight, the insides were filled up with batteries, again referring to the FRED EasyPort for realistic weights, taking into account that these devices do come with bigger displays and extra features, leading to a weight estimation of ca 800-1000g, whereas the FRED EasyPort weighs 490g.

Visual aid: For visual instructions, each device was fitted with a collection of instruction screen pictures, showing each step visually. These were exchanged manually throughout the tests.



Voice instructions: Lastly, voice instructions were recorded for each instruction step, and played for the users with a set timing, as they progressed through the usage scenario.

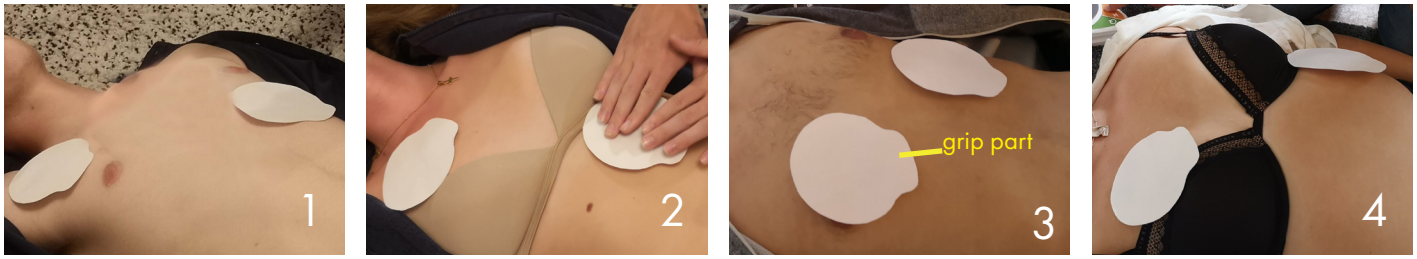
7.3 Mockup tests - PIN

Initial interaction: Two testers placed the device on the ground before opening the lid, while the other two testers opened the case while holding it in their hands. The two who opened it on the ground felt like they had a better overview of the components compared to the two who opened it while holding the device. The lid should have had a tactile grip or indication showing more clearly how to open it.

Electrode pad storage: The electrode pads where placed on top of the device, inside of the lid. When opening up the device, Tester 4 had the issue of the electrode pads falling out during opening. Overall opinion was that the storage did not feel thoroughly thought out and needed to be worked on.

Device shape: The shape was seen as interesting but not very prectical for storing in bags or backpacks, as its' more unconventional shape would be hard to fit together with other everyday objects. Testers also said that they would prefer having a more clear orientation of which side was up and which was down, as well as front and back. once opened, the shape did help creating a clear hierarchy of the interface elements, with the screen being the main focus.

Electrode pad placement: Tester 3, who had no previous AED experience, placed the top electrode pad too low, but the others were able to follow the visual instructions correctly. The general pad size was seen as having a good and comfortable size, though two participants felt a bit unsure if the direction of the grip parts should have a certain direction on the chest or not, as this was not indicated in the illustrations. For Tester 4, the round electrode pad shape was less practical for the curved rib shape of the "victim".



Button interaction: The size of the buttons were good, though for some a bit big. It was pointed out that this could be good when used by elderly people. The shape was accepted, though one tester said they would prefer a more traditional button shape, for example circular. The colors (green for start and orange for shock) were well understood by all testers, and interaction order of left-to-right did not cause any confusion.

Physical CPR support: Concept PIN was the only mockup with physical CPR support. With this feature, the testers had different approaches. Tester 1 accidentally pressed the start and shock button while performing the HLR, Tester 2 used it as originally intended, but placement was too high up due to the physique of the "victim". Tester 3 used an alternative pressing position which they found more comfortable, while still achieving the intended result, as the device still focused the pressure on the correct point. Tester 4 placed the device in another direction, since this was more suitable for the body type of the "victim". Overall, this physical CPR functionality was deemed somewhat unneccessary and felt like adding an extra step.

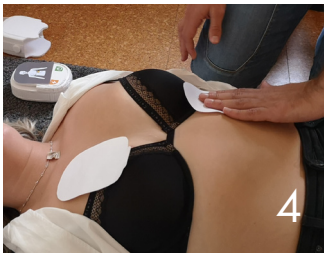
7.4 Mockup tests - CATCH

Initial interaction: All four testers opened the device while holding it in their hand, and then proceeded to lay it down on the floor. In three out of four testers, the body of the case was gripped during opening, rather than the handle. This was deemed as giving a more stable grip than the turnable handle could offer, and this static grip was also needed in order to separate the magnets holding the device in the case. The shape towards the bottom of the case was understood clearly as the interaction area for gripping the device, and the testers understood the device removal/opening without issue. Half of the testers said the device was heavier than they would have expected from its size.

Electrode pad storage: The electrode pads were stored in a slim compartment behind the device screen. The grip part of the pads were sticking up above the screen, and the testers immediately understood that this should be interacted with. The storage itself was well understood, but there was concern regarding the sturdiness of the screen, as it was fairly thin and lacked support behind it due to this electrode pad storage compartment.

Device shape: The shape was well liked by all participants due to its practicality. With its mostly rectangular shape, it was deemed more easy to store in bags, and its compactness gave it the most liked size out of the three models. The rounded corners were also liked for their more "friendly feeling". The case-device orientation was understood as being practical overall, but there was also distrust and concern about the sturdiness of the magnets holding the device to the case, and if these magnets would wear down over time, risking that the device would fall out of the case. It was pointed out that this would be especially concerning if you had to run with the device to bring it to a victim. All four testers said they would feel more comfortable holding it with both hands in that case, which would make it less practical.

Electrode pad placement: All four testers agreed that a more rectangular electrode pad shape was easier to place on the "victims", since they could be angled or turned in order to fit the shape of the chest and ribs better than the round electrode pads. This shape was also easier to bend according to the female anatomy. With this electrode pad shape, the testers did choose quite different placement directions, but they all felt comfortable with their placements, and for real electrode pads, the differences in direction (horizontal or vertical) would not impact the effect of the shock.



Button interaction: Out of the three models, the buttons for the CATCH concept was said to have the most "normal" and expected size. They were big enough to be clear, without feeling over dimensioned. What did confuse all testers was the interaction direction of right-to-left, which they did not find intuitive. One tester pressed the wrong button, and the other three had to spend an extra second realizing the order/symbols.

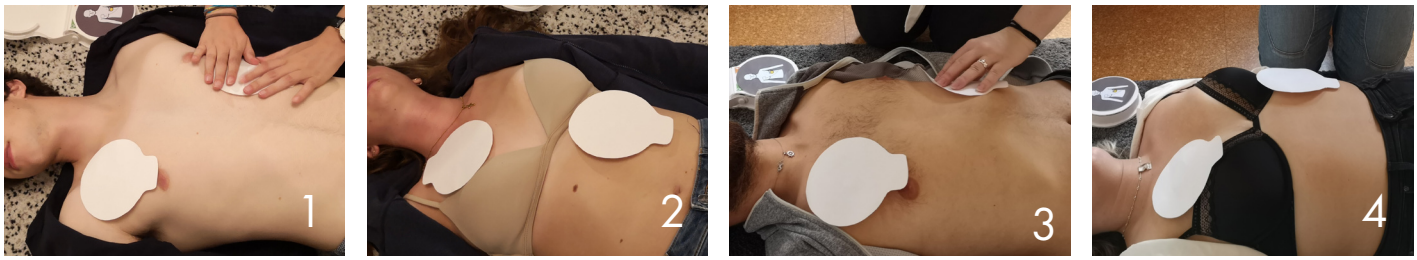
7.5 Mockup tests - FOLD

Initial interaction: Two of the testers opened the case after putting it on the floor, while the other two opened it while holding it in their hands. Independent of placement, all testers found the opening easy and intuitive. The slightly protruding rim around the top of the lid gave good support in opening the case, and having the device built into the case itself was highly appreciated by the testers, who liked the compactness and only having one main part to keep track of. They also had the impression that this made the start quicker, since the starting process was seen as being more straightforward.

Electrode pad storage: Once laid out on the floor, the handle gave a slight angle to the lid, giving good access to the electrode pad storage located inside the lid. Three of the testers grabbed the electrode pads by the grip part, while one testers managed to grab it from the side, which also seemed to work. This dedicated electrode pad storage area was very well liked by the users, and was deemed to be the best storage alternative out of the three models, since it was well located, easy to find, and clearly separated from the device itself without compromising the compactness.

Device shape: The general first impression of the shape, was that it resembled a purse or handbag. This was said to not neccessarily be something negative, but the more unconventional shape made the testers think it would be more difficult to store. The testers also found the handle to be slightly too tight and narrow.

Electrode pad placement: Similarly to the testing of the PIN model, the round shape of the electrode pads were more difficult to place on the female "victims", due to curvature. Here, the lower pad often had to be placed more in the middle, instead of directly under the ribs. The pads were also bigger, making them even harder to place correctly.



Button interaction: The buttons were deemed as being way too small and hard to read, with the added negative of them having an unconventional edgy triangular shape. Here, all testers expressed the wish to have bigger and more "normally" shaped buttons instead. Three of the testers also mentioned that they thought placing the buttons underneath the screen would make more sense, since they did not want to cover the screen while interaction with the buttons. The interaction direction of left-to-right was clear.

7.6 Key insights

Intuitiveness: Even for the inexperienced test persons, the principle of AED use was quick and easy to learn.

Device and case shape: A rectangular shape is preferred for storage and transport purposes, as it fits better into bags and backpacks, and can be placed on a table surface either lying down or standing up. Rounded edges and corners make the grip better and more comfortable.

Case design: The foldable case was clearly deemed as more practical - mainly due to the case and device being directly connected, as well has offering a clear overview of components directly when opened.

Size: smaller and more compact sizing is preferred.

Electrode pad use: the bigger electrode pads where deemed as hard to place correctly on the body, as the bigger surface did not adapt well to the curves of the human body. This was especially true for use on female bodies (*note: tests were conducted with paper electrode pad mockups, and real electrode pads are somewhat more flexible in material. Even so, they are not flexible enough to counter the issues experienced during the mockup testing*).

Electrode pad storage: dedicated and built-in electrode storage is seen has having many advantages, such as giving a clear overview of components, and offering a less confusing and less cluttered kit.

Buttons: button size and shape is very important. Medium- to big buttons are preferred, and round buttons are more recognizable semantically. Color-coding references can differ, and action order of left-to-right and top-to-bottom is generally better recognized than the other way around.

Visual aid: íllustrations are clear and easily understandable. After the first test round, visual aids are barely referenced any more, and test persons mainly rely on voice instructions instead. Screens are important for learning the principle but not neccessarily used by more experienced users. The illustrations should not be too general, but rather as accurate as possible without overcrowding the details.

Voice instructions: after initial support of visual aids, the voice instructions followed as the mainly used support throughout the rest of the test rounds. Instructions in themselves were clearly understood, but the pre-set wait times in between steps frustrated users. CPR rhythm counting was especially appreciated.

CPR feedback: sensors built into the electrode pads were clearly preferred to having physical CPR support. The user flows including the sensors were better understood by the testers and was seen as being more straight forward.

7.7 Highest rated features

Based on the mockup testing, the highest rated features and attributes were identified fur further ideation.

PIN

+ Button interaction left-to-right
+ Buttons underneath screen
+ Green and orange button color

CATCH

+ Middle-sized buttons
+ Rectangular shape
+ Rounded corners
+ Compact size
+ Rectangular electrode pad shape
+ Handle not neccessary
+ Can be gripped with one hand

FOLD

+ Built-in case
+ Opens up semi-flat
+ Electrode pad storage inside lid
+ Tactile lid opening

7.8 CONCLUSIONS 3.0

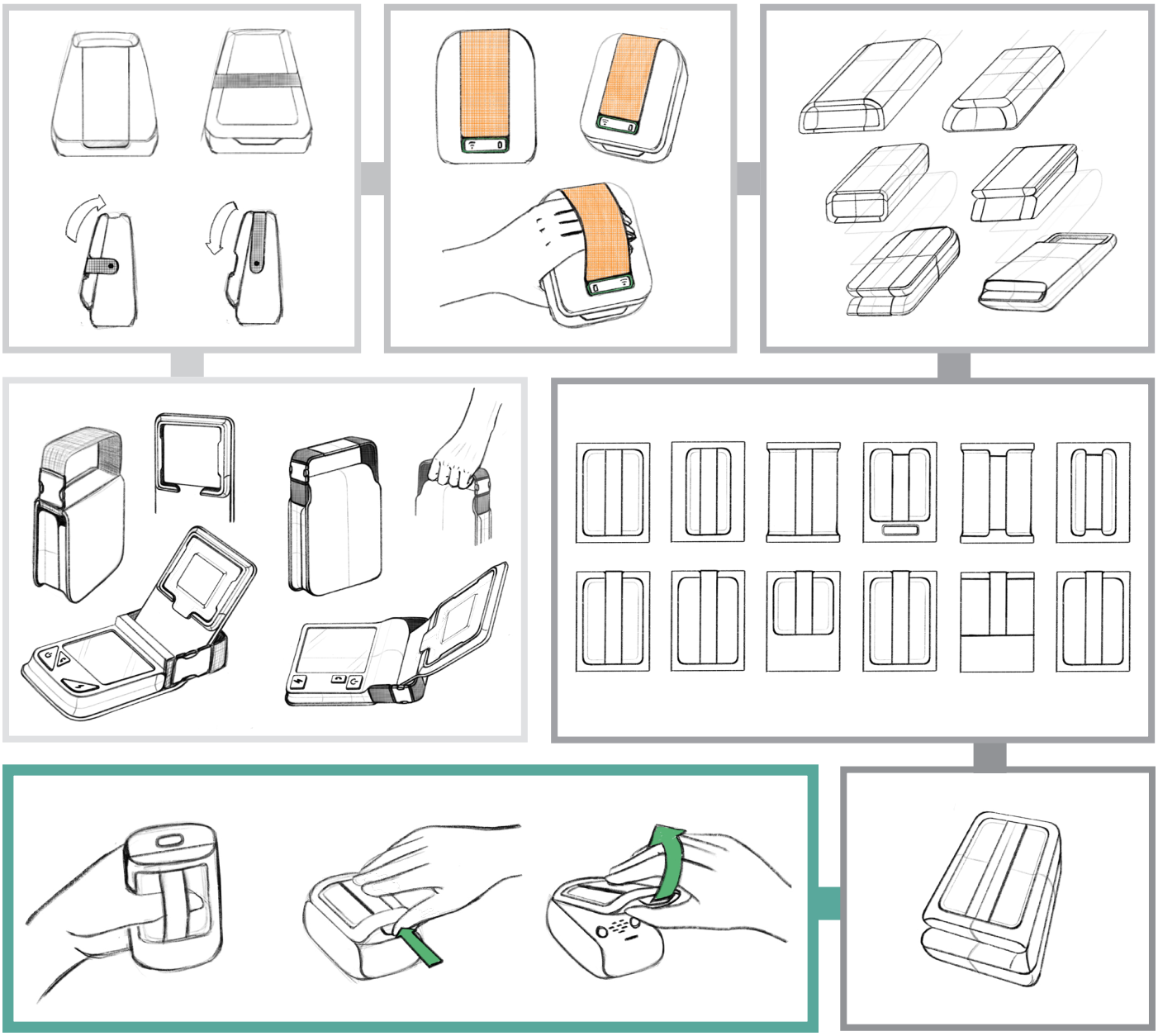
The physical mockup testing was immensely helpful in offering insights related to the device interactions, often shining a spotlight on pain points or advantages that otherwise would not have been thought of.

After these tests, it was clear that there was not one clear “winner” that should be further developed, but rather positive and negative features to each of the three concepts. This lead to the insight that the best way forward would be to try and combine the tops features of each concept, also taking into account the various preferences gathered throughout the tests.

8.0 FINAL DESIGN

For the final ideation, the highest rated features and attributes of the previous designs were combined into a new direction, aiming to take into account the learnings from all previous research, ideation and testing.

8.1 Sketching



With the highest rated features in mind, the ideation continued with exploring variations and combinations of these features. Looking more closely at details and specific elements, such as the case opening area and handle variations, resulted in a design adapted to be held securely directly in the hand, with clear tactile and semantic indications of handling, placement and opening interactions.

Device shape: The device has an overall rectangular shape, making it easy to store in bags, and enabling it to be placed either horizontally or vertically. At the same time, the corners are clearly rounded, making it comfortable to grip in the hand.

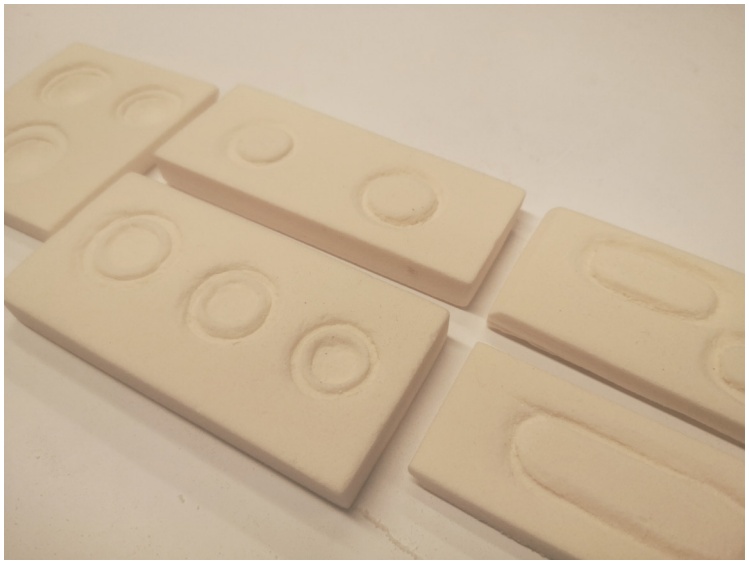
Handle: Instead of a traditional full hand handle, this handle is adapted to a full-hand grip of the whole device. Consisting of an elastic band which secures either the thumb or fingers (depending on holding preference) it supports the grip, while remaining flexible and discreet.

Opening: With a curvature semantically indicating its opening function, the lid is opened by pressing a big wide button. Once opened, the user is presented with the electrode pad storage, which covers most of the lid's inside area.

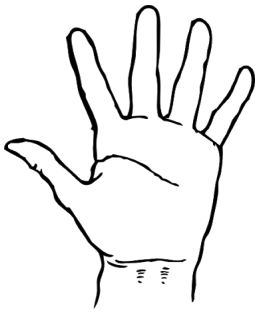
8.2 Buttons & dimensions

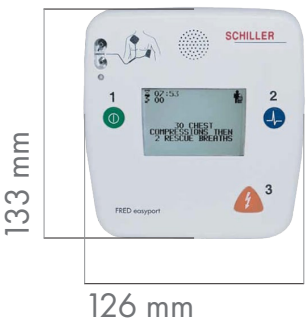
Before making the final foam mockup, details like the buttons and dimensions were tested and defined.

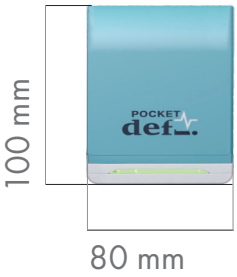
Buttons: The ergonomy of the buttons was tested using foam mockups, exploring different sizes, depths and concave vs convex designs. These button mockups were then tested within the design school, making sure to include testing with different hand sizes and finger lengths.

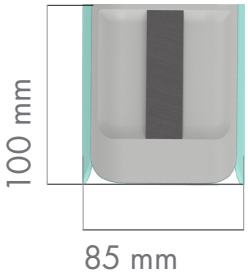


Device dimensions: The device dimensions were defined after comparison with three other models which are either sold or under serious development. Philips Heartstart, as it is the only FDA approved AED for over-the-counter sales to private users. Fred EasyPort, as it is the smallest AED being sold on the market. PocketDefi, as it was used as a big inspiration throughout the development and ideation in terms of what could soon be possible size and functionality wise. Furthermore, the size was also adjusted based on the tested cardboard mockups, resulting in a size very similar to the PocketDefi, only slightly wider to offer a more comfortable grip.









8.3 Foam mockup

To properly test out the size, ergonomy and features, a foam mockup was made in 1:1 scale. To this, an elastic band and thicker foam (in order to take the packaging into account) mockup electrode pads were added.

With this foam mockup, several factors were evaluated. Size and dimensions in context of holding the device in the hand, comfort and effectiveness of using the elastic band as a handle substitute, ease of use when opening the case and removal of the electrode pads, as well as the interaction with the buttons.

8.4 CMF strategy

Being a portable device intended for bringing with you everyday, the goal was to make the device more discrete than current AEDs on the market. The goal of current AEDs are to bring attention to themselves in busy public spaces, which is why they are often made in bright and alerting colors. As the usage scenario and target group for this product was very different, it did not need this attention-grabbing functionality. Instead, a more discrete color scheme would enable the users to casually bring the device with them, without having to draw attention to their medical condition.

With this said, an AED is still a medical device, and the goal was not to move away completely from this fact, and confuse it with other portable devices such as bags, speakers or accessory cases. With this in mind, the color scheme kept to more discrete, yet traditionally medical, colors for the housing. But the main focus remained on the usability elements, which were identified through neutral tones of grey, making them independent from any housing color, avoiding any confusion in terms of functionality.
All non-usability colors were also chosen to have a clear contrast with the usability colors, in order to avoid any confusion in interaction.

As for materials, the focus remained on functionality, making use of rougher plastic surface textures which can withstand outdoor use and potential scratches, as well as stabilizing rubber details to keep the device sturdy when placed on slippery or uneven surfaces. The elastic band, which is the sole textile component on the device, would be flexible enought to adapt to different hand sizes, but sturdy enough to keep its' elasticity even after repeated use.

Usability colors

RAL 000 30 00
main interactions

RAL 000 70 00
secondary interactions

RAL 000 90 00
neutral surfaces

Housing colors

RAL 190 70 30
hygiene green

RAL 450-5
muted red

8.5 Problem solutions

previous problems	new solutions
• too expensive	• remove screen and lower material costs
• desire for portability	• reduced size by 75% (to Philips Heartstart)
• replacement parts not easily available	• rechargeable battery
• would like to bring on travels	• smaller battery and easy to store in smaller bags
• real-time feedback would be better	• built-in sensors
• CPR feedback desired	• built-in accelerometers
• too many loose parts	• built-in outer case with dedicated electrode storage

8.6 DESIGN CONCLUSIONS

Through the compilation of several research and design phases, the final design grew step by step through the different iterations, each one taking into account the learnings from the previous ideas and continuously developing and improving. By using this approach, the final design ended up being firmly based on the needs and desires of real users, with a strong focus on user experience supported by testing and evaluation.

9.0 DIGITALIZATION

Throughout the development of the physical AED device, it became clear that the needs of a personal AED user in today's digital society, will often transcend what a purely analogue device could offer.

With digital technology enabling features related both to the device's overall functionality, as well as its software and general interaction possibilities in relation to the user, it was clear that the benefits of pairing the physical device with an app and IoT features were worth exploring.

9.1 Initial ideation

On the market currently, there already exists some models with the possibility of connecting to wifi networks, and this functionality was also mentioned by some of the target group respondents. By bringing the AED device into the digital space, another level of possibilities opens up in terms of functionality and ways of simplifying the usage process. For a device intended for personal use, the move to digital integration makes a lot of sense, seeing as our modern society nowadays is very used to digital products and the Internet of Things (IoT). With this in mind, a digitally integrated AED device for personal use has great potential of being generally accepted.

Even so, internet connectivity and smartphone access can still be limited or at times unaccessible. For something as crucial as a life-saving device, this uncertainty could be detrimental in an emergency situation. The benefits of digital connectivity can not be made at the expense of security and reliability. With this in mind, it was of outmost importance that the device would offer all basic functions of a traditional AED during analogue, disconnected, use. Meanwhile, the digitalization would add extra value for the user at times when they can or choose to be connected, but would not control any of the crucial features.

To make this additional digital experience as seamless as possible, the idea was to pair the device with an app. This way, the main digital features would be easily overviewable, all gathered in one place and directly accessible from the user's smartphone.

A brainstorming was done in order to identify the most useful features of an AED app.

Device status: Quickly being able to check the status of the device without having to pick it up. Focused on battery level and connectivity. Since the device is mainly intended for personal use, the app could also be connected to the devices of friends and family, and offer status overviews for several connected devices.

Emergency contacts: Collecting all important emergency contacts in one place. Could be used by the user or a bystander in case of an emergency.

Software updates: One of the main uses for current wifi-connected AED devices is being able to easily update the device software directly as new versions come out. This way the user does not have to hand it in to the manufacturer for updating, and new updates can also be rolled out to the users much quicker.

SOS function: Since the owner of the AED device is often the person in the risk group of experiencing a SCA, and thus cannot use the device on themselves, this function offers the possibility of sending out an SOS message to all emergency contacts listed in the app, together with a current location in order for them to come assist the user. This is extra useful for people living alone or far away from the nearest hospital, as nearby neighbours, friends or family would often be able to get there quicker than an ambulance. Being only two clicks away (one for opening the app and one for pressing the SOS button), it also enables the user to quickly alert for help without having to talk, as would be required with an emergency service call.

Video tutorials: Offering the chance to learn how to use the AED before actually using it.

9.2 SOS+GPS function

When using the app, pressing the SOS button on the start page will send out a SOS message with attached location tracking to the actively chosen emergency contacts. This uses the phone's GPS locator as well as the phone network and enables quick and easy alerting, as time is of the outmost importance in a SCA situation. This function is mainly targeted towards users who are experiencing a SCA, without the possibility of using the device on themselves.

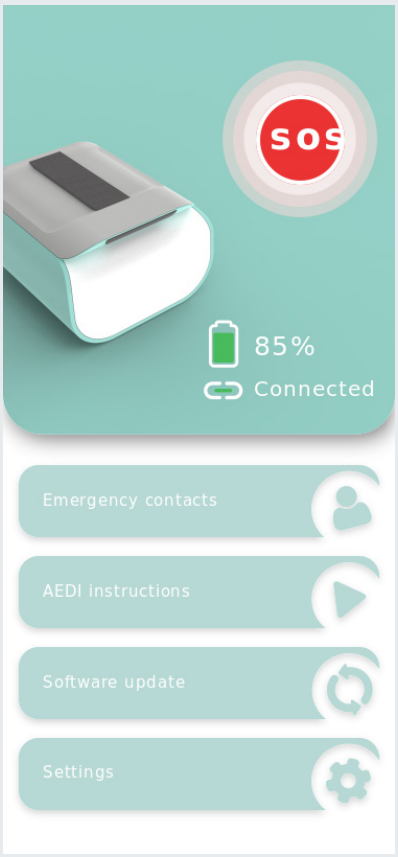
As an analogue alternative, the physical device itself also offers an SOS call button. This function does not require a phone or network connection, but instead uses a GSM receiver in order to call the local emergency service number and alert them of the situation. Contacting emergency services should be one of the very first steps in a SCA situation, but having to call on your phone while trying to set up the AED device can be overwhelming. With this built-in SOS call functionality, the step of calling is directly integrated into the device usage journey, eliminating the need for an additional call on the phone. When paired with the app, the physical SOS call button will also simultaneously send out the SOS message from the app.

GSM stands for Global System for Mobile communication, and generally needs a mobile signal connector, but does not require a SIM-card in order to work[1]. The function of a SIM-card is to authenticate the caller on a network, but since emergency calls do not require any network authentication, emergency calls can be made even without a SIM-card[2]. This avoids the user having to pay for a subscription with a mobile phone operator just to access the emergency call function.

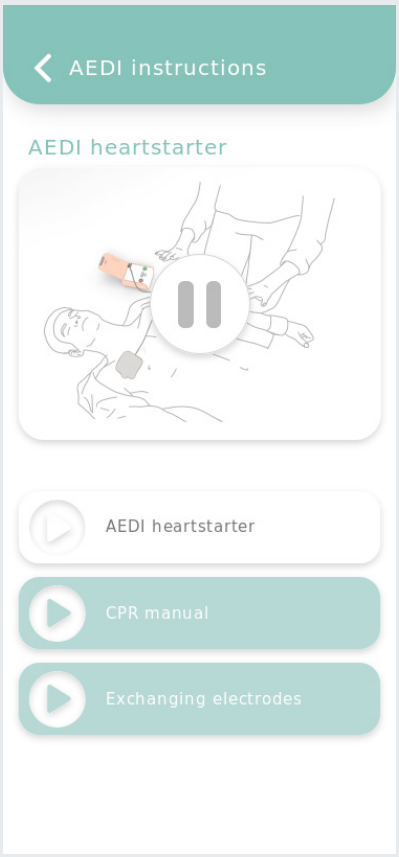
1 https://www.techtarget.com/searchmobilecomputing/definition/GSM
2 https://www.scienceabc.com/innovation/how-can-mobile-phones-make-emergency-calls-when-theres-no-network-coverage.html

9.3 App interface

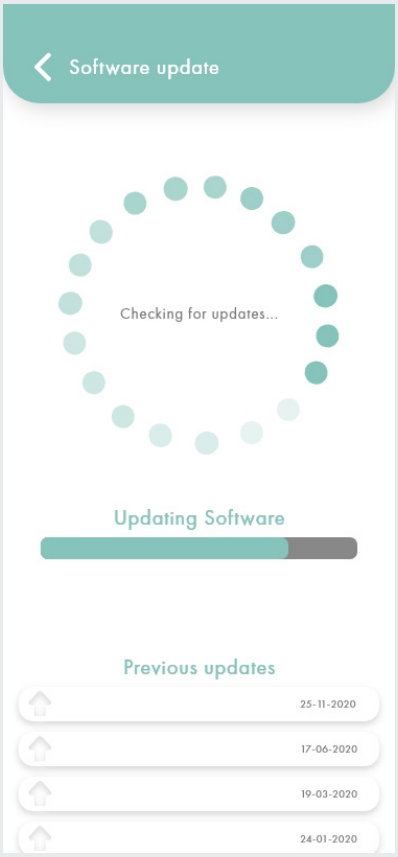
START SCREEN



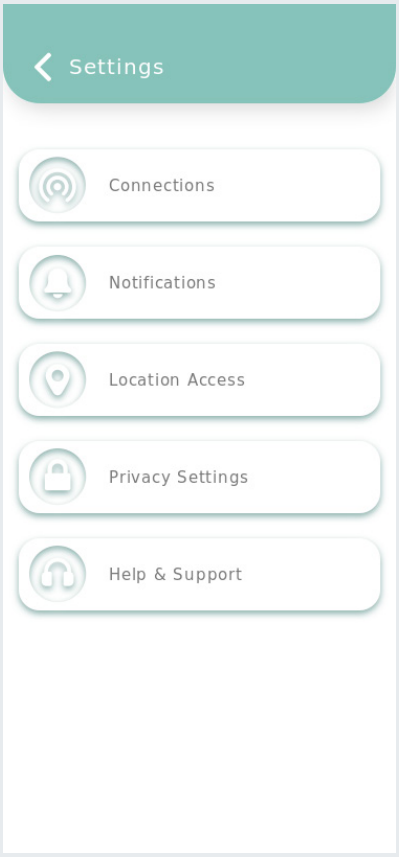
USAGE INSTRUCTIONS



SOFTWARE UPDATES



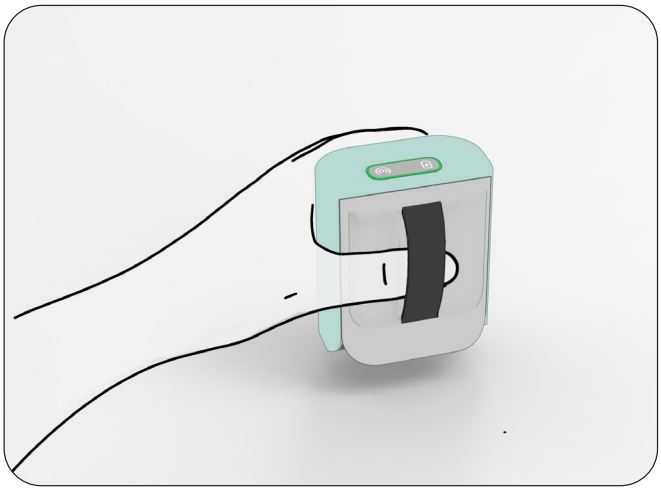
SETTINGS

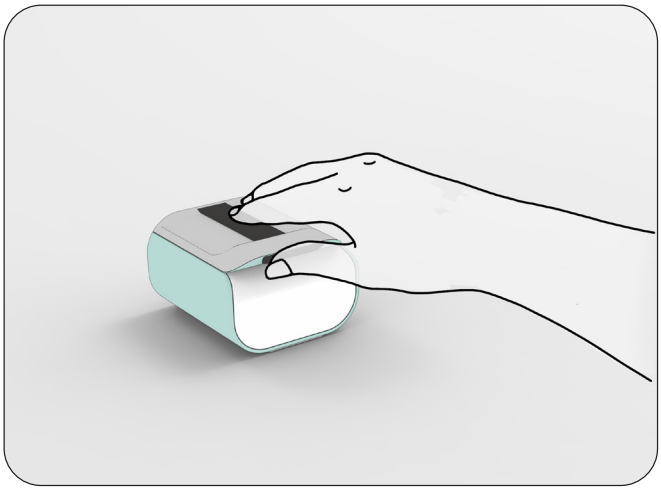


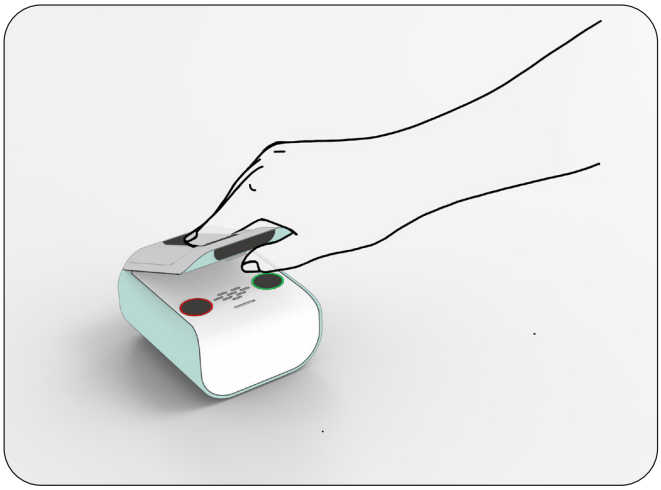
10.0 FINAL CONCEPT

The full functionality of the final concept was illustrated through a complete user scenario, which step by step shows how the device would be used in a SCA emergency situation.

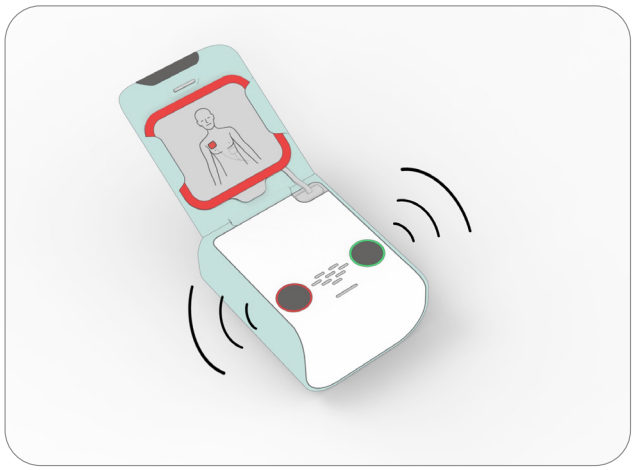
OUTER INTERACTIONS



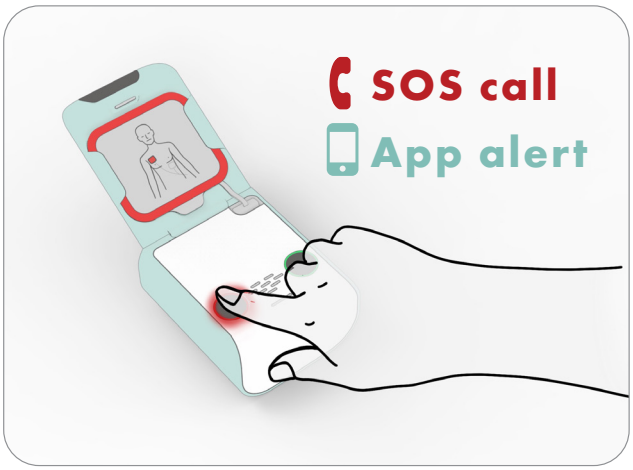




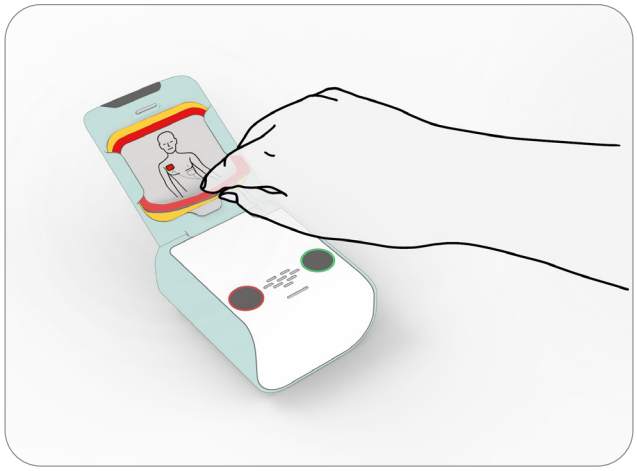
USER SCENARIO



1. Device turns on when opening. Voice instructions begin.



2. Press flashing red button for SOS call and app alert



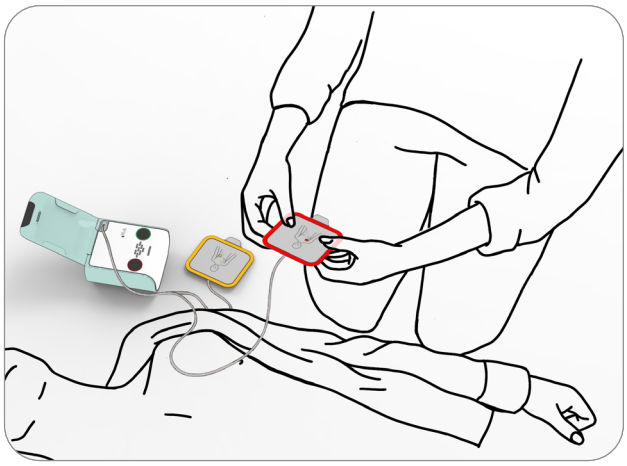
3. Remove electrode pads

4. Heart rhythm is analyzed after attaching pads to chest

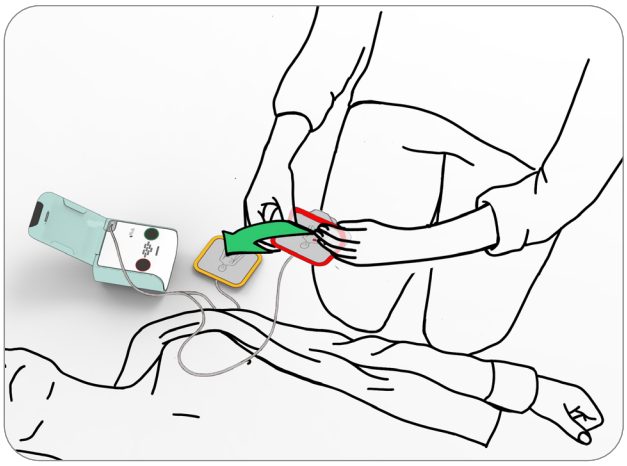
5. Press flashing green button to administer shock, if advised

6. Give CPR while getting real-time voice feedback on rhytm

ELECTRODE INTERACTION



1. View illustrations



2. Remove protective film

3. Attach first electrode

4. Attach second electrode

TECHNICAL SPECS

150 joules

1200 mAh battery, rechargeable
>20 shocks when fully charged

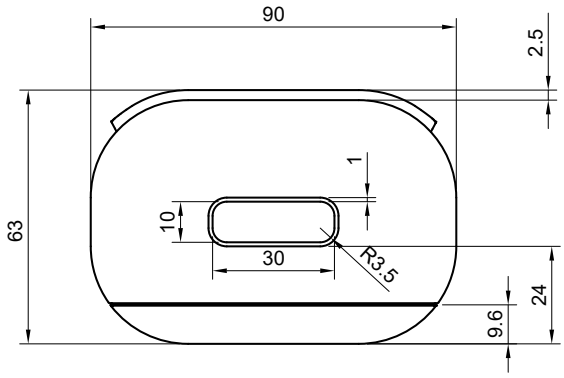
SIM card-less
GSM Emergency call

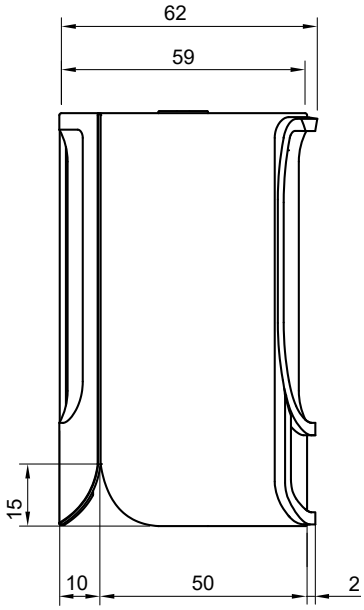
In-app
GPS Tracker

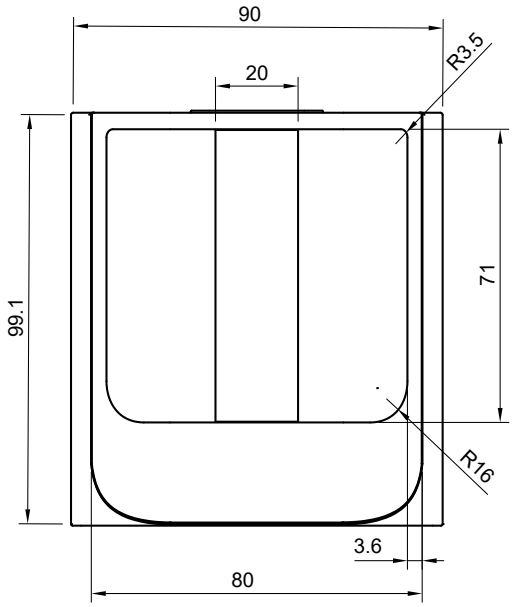
100x85x60 cm

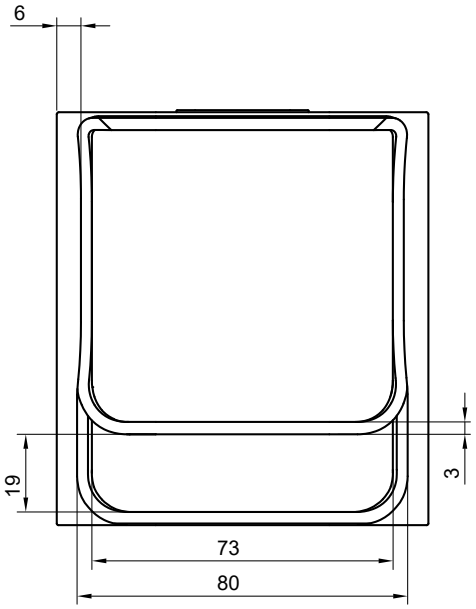
2,0kg

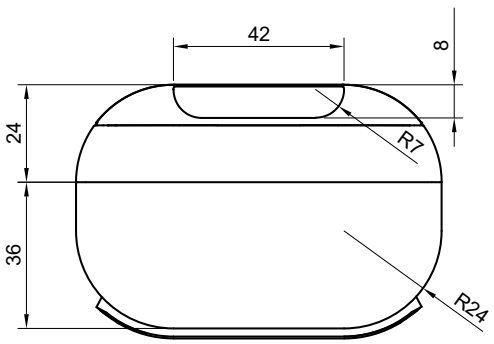
TECHNICAL DRAWING







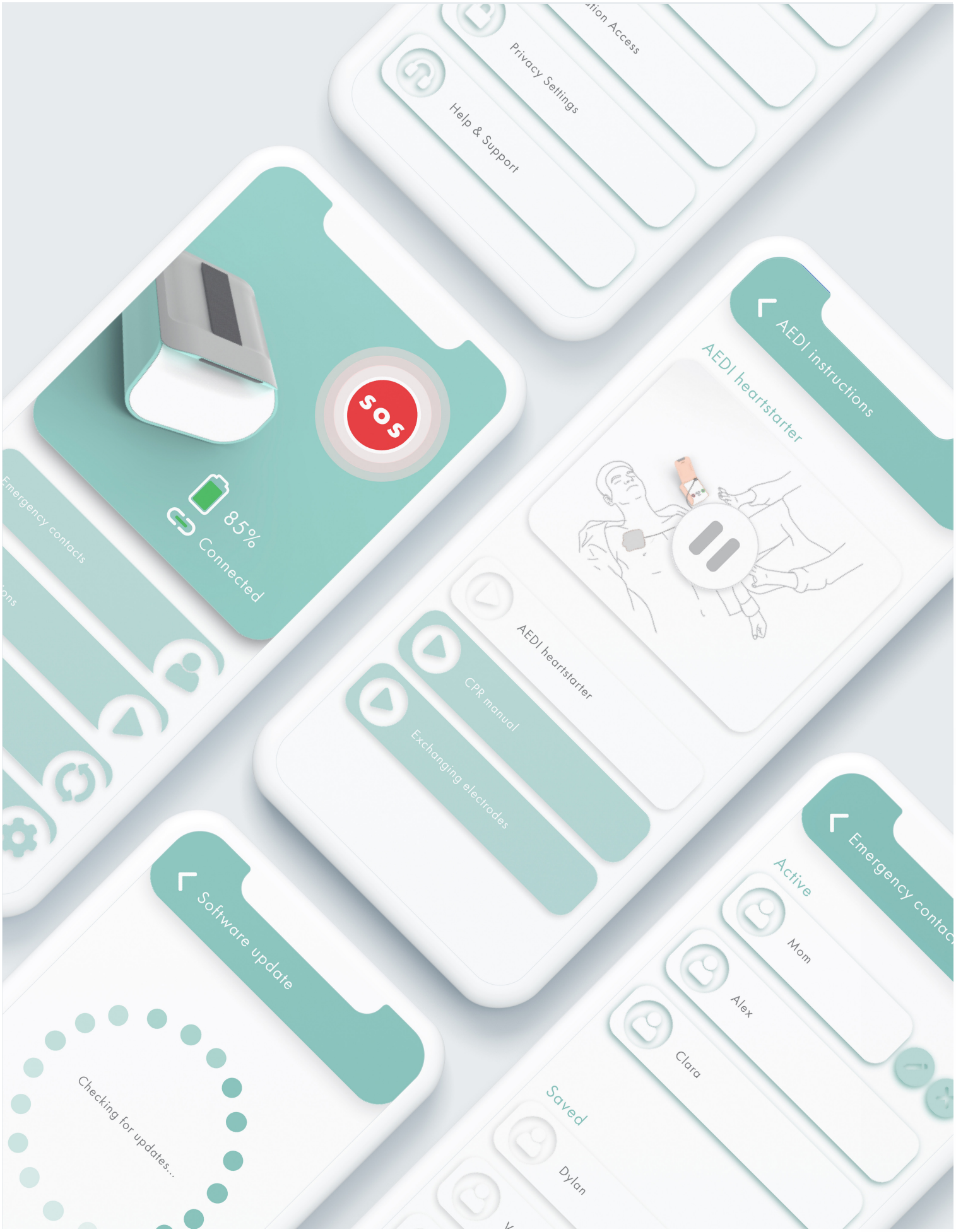




11.0 RESULTS

The following chapter features a full overview of the resulting product, named AEDI. It includes the app interface mockup, as well as closeups of the various components and features, CAD-modeled in Solidworks.

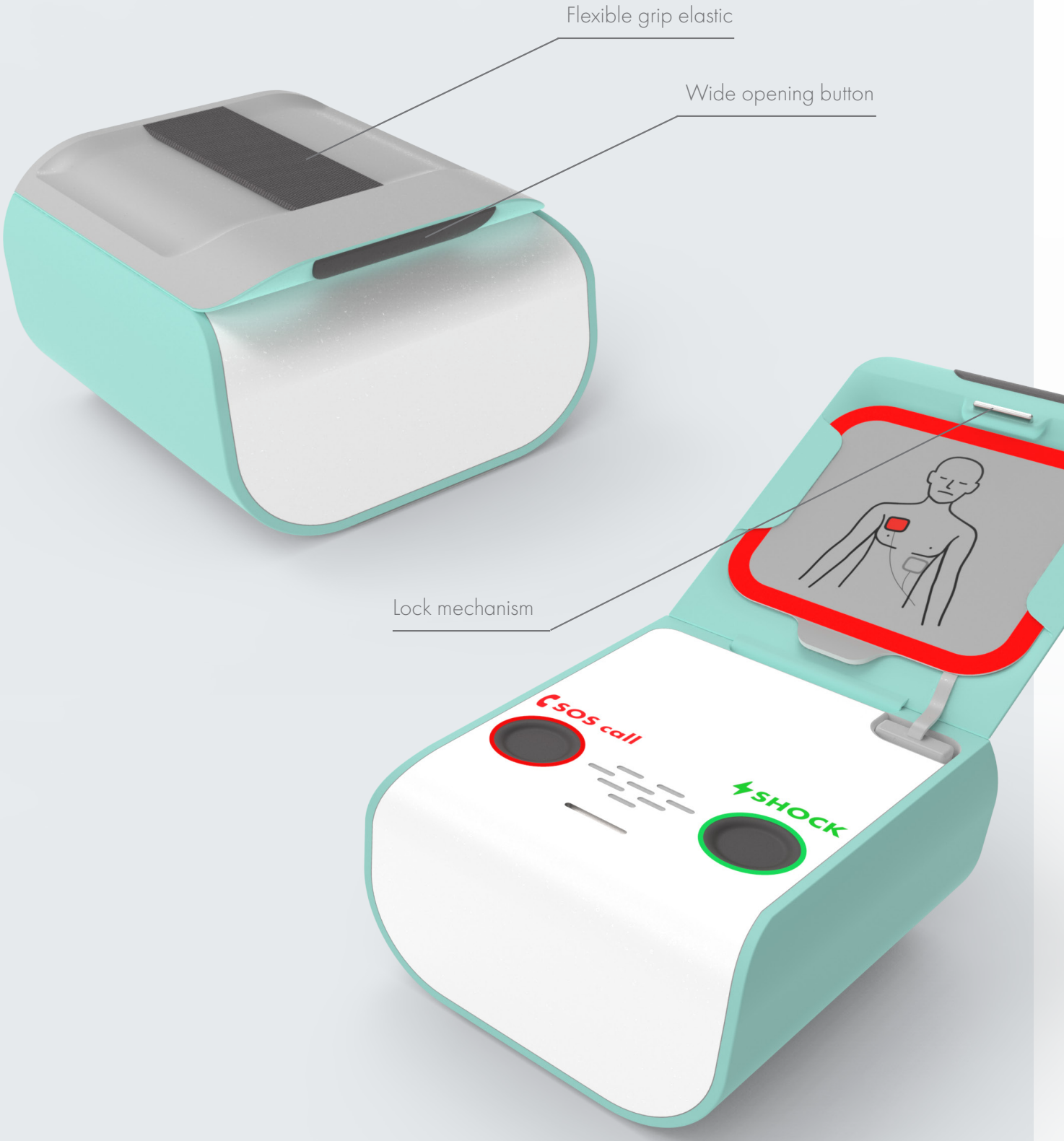
APP INTERFACE



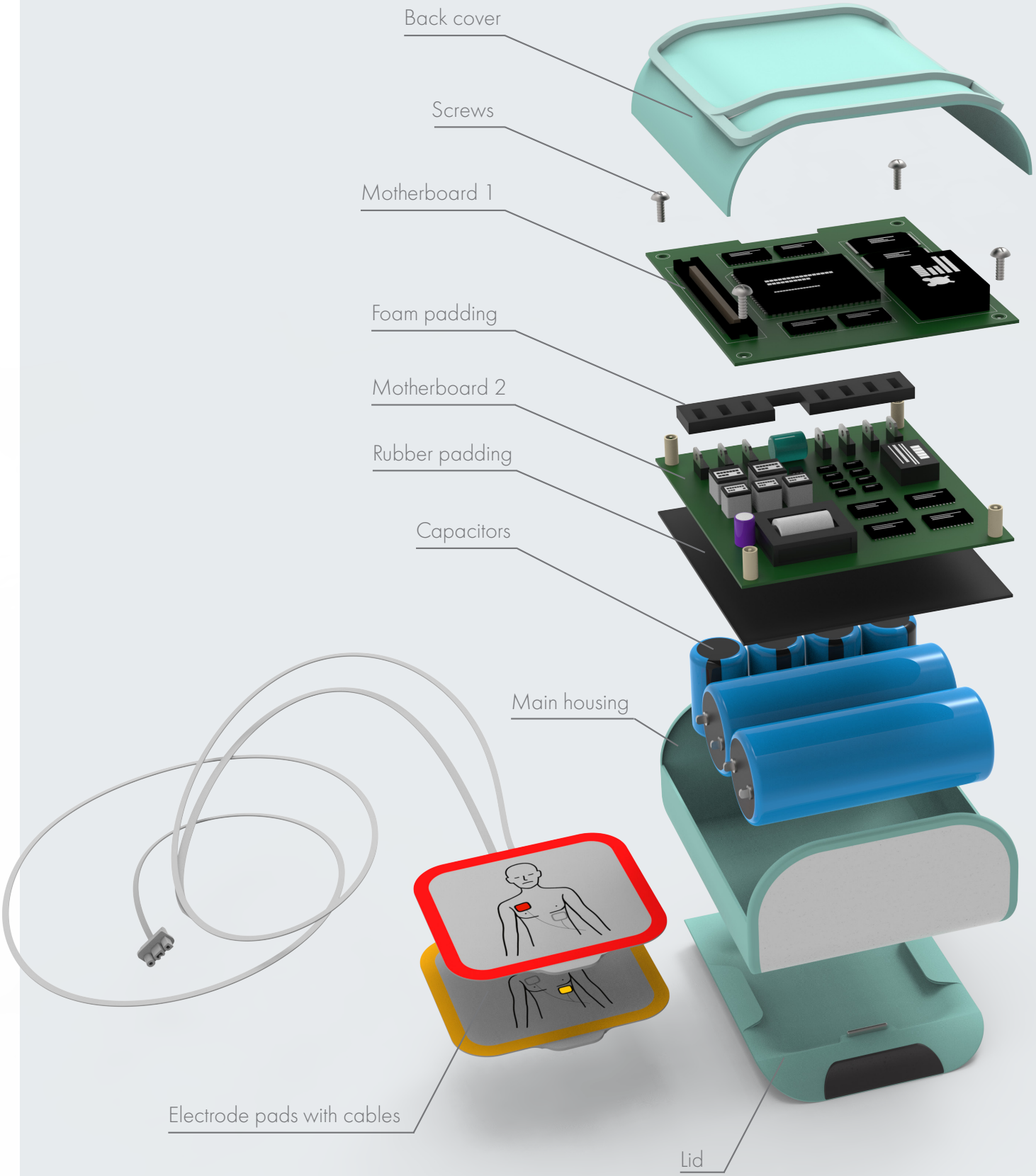
USABILITY

main interactions

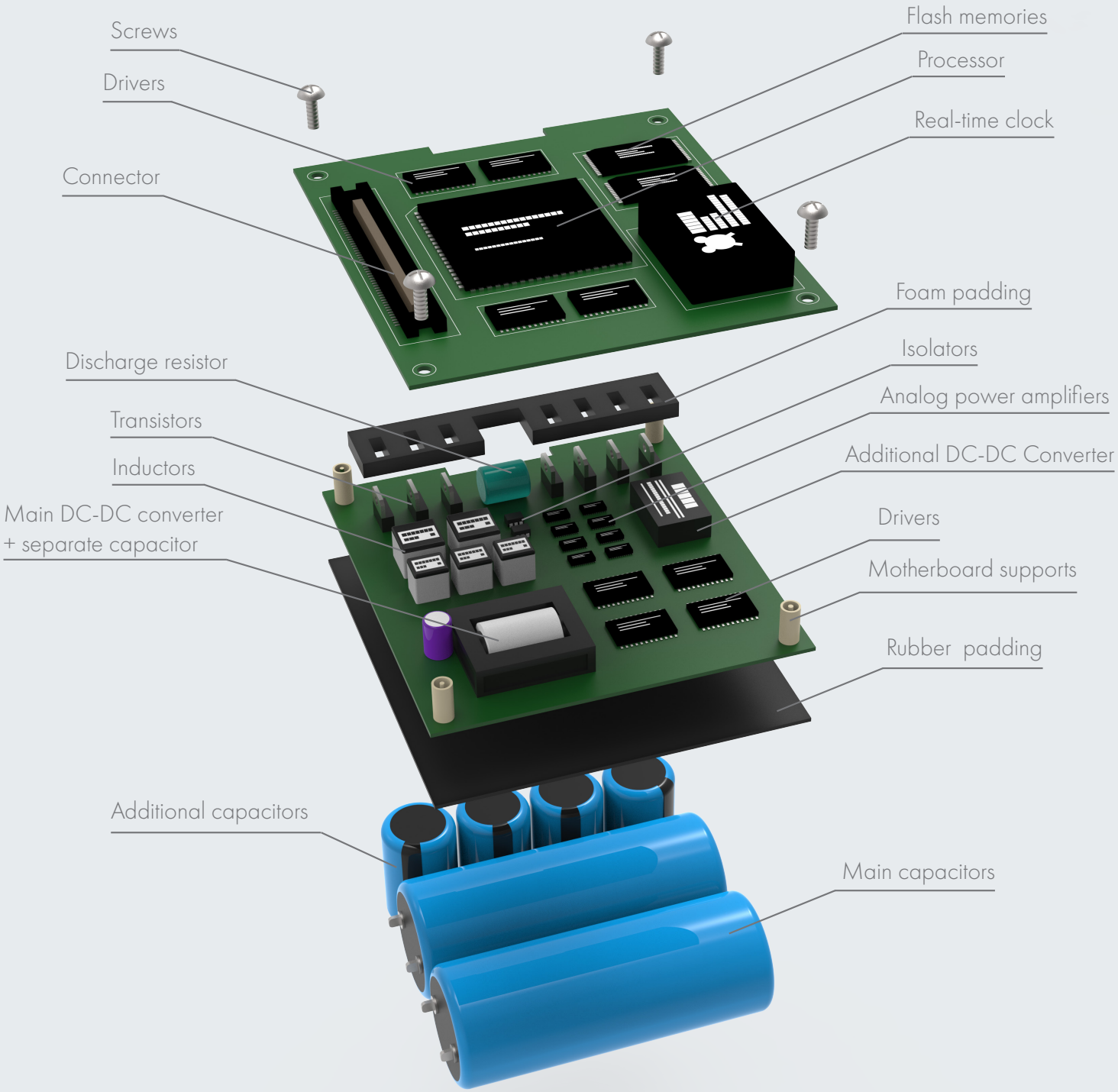
secondary interactions



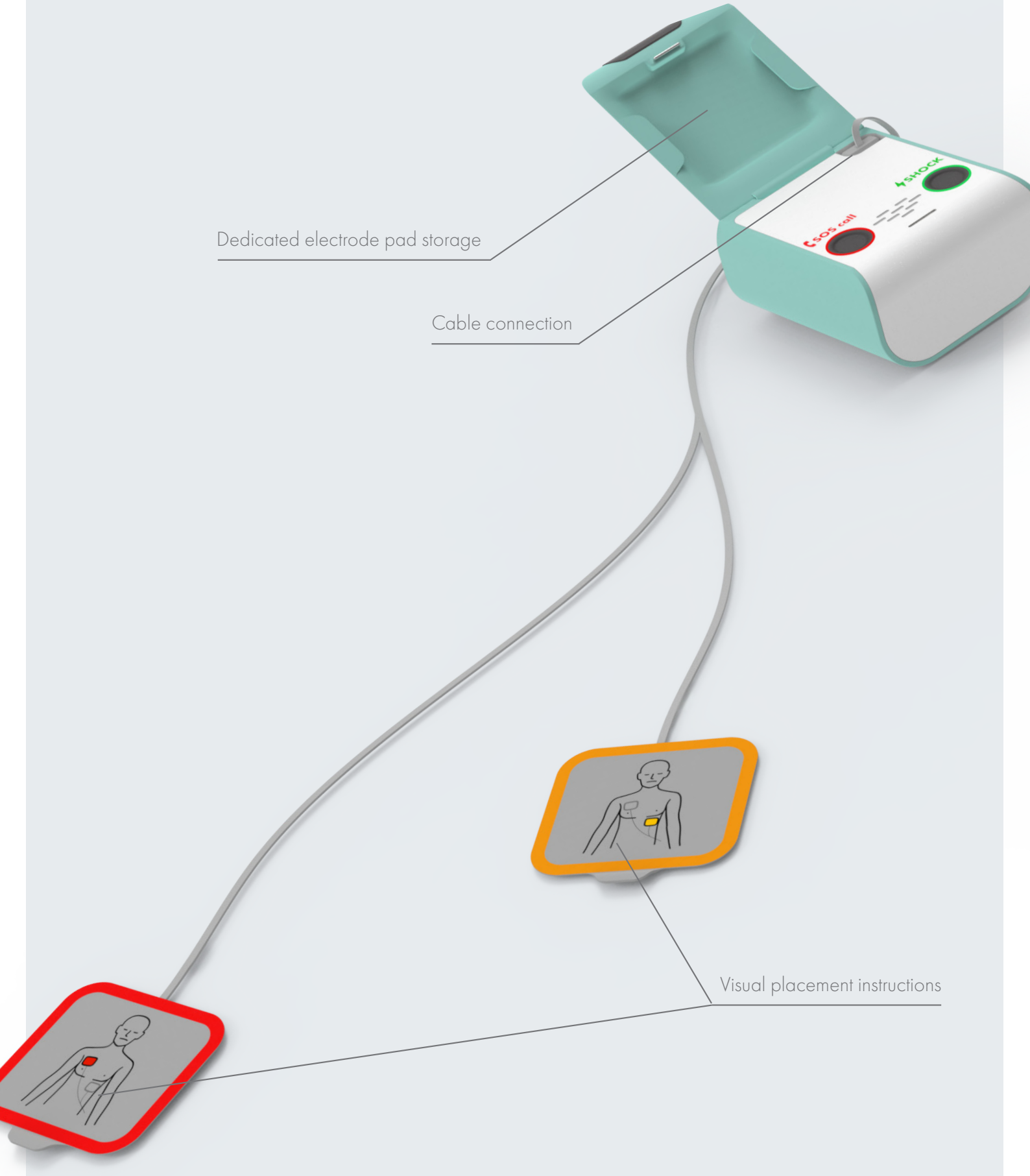
COMPONENTS


Back cover
Screws
Motherboard 1
Foam padding
Motherboard 2
Rubber padding
Capacitors
Main housing
Electrode pads with cables
Lid

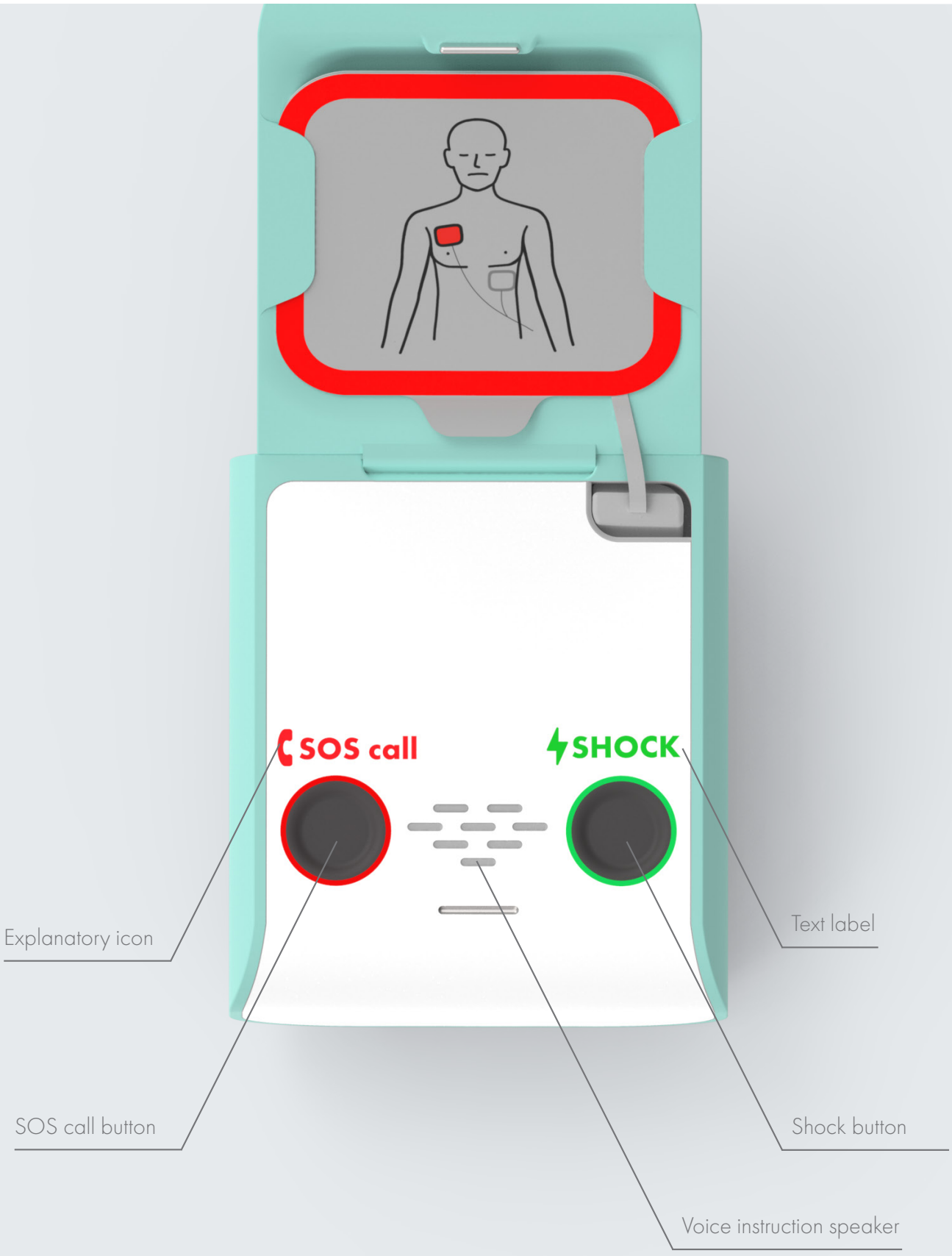
TECHNICAL COMPONENTS



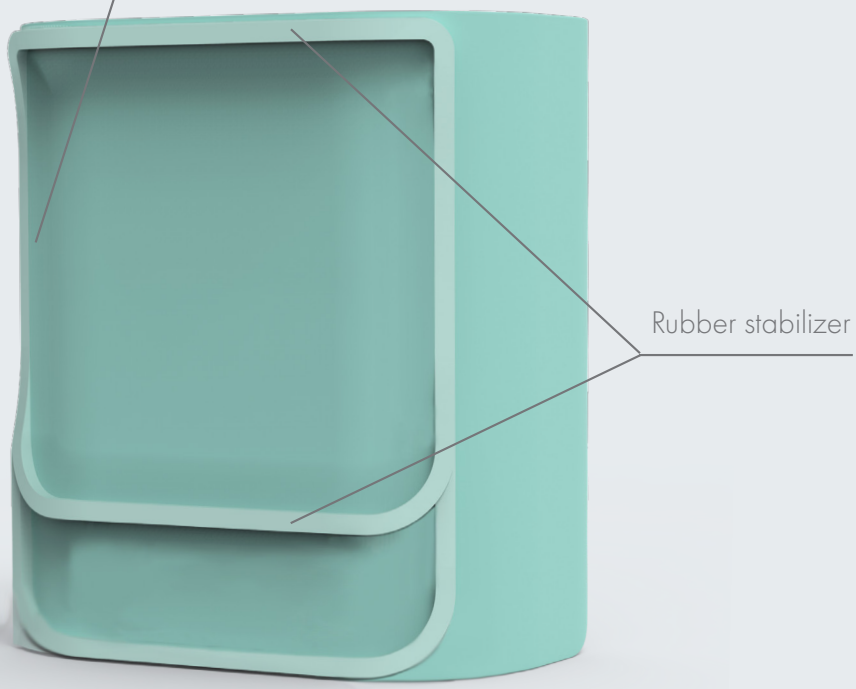
ELECTRODE PADS

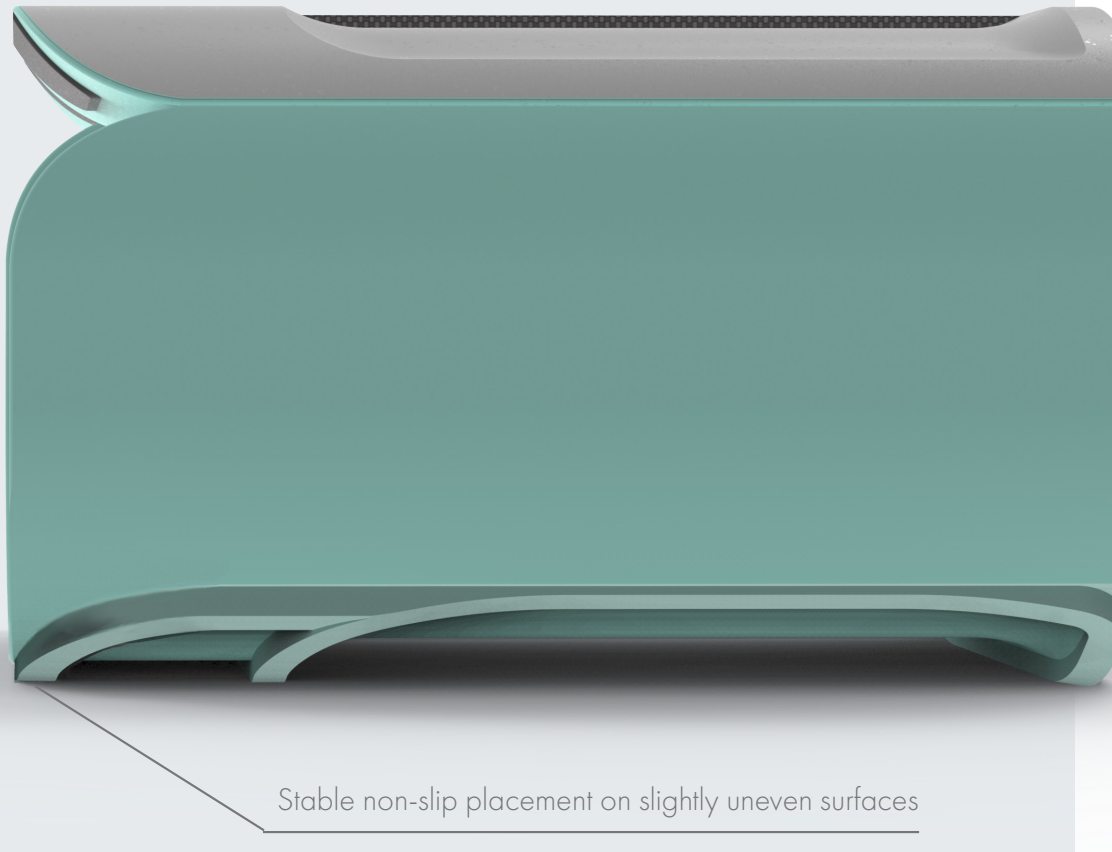


PHYSICAL INTERFACE

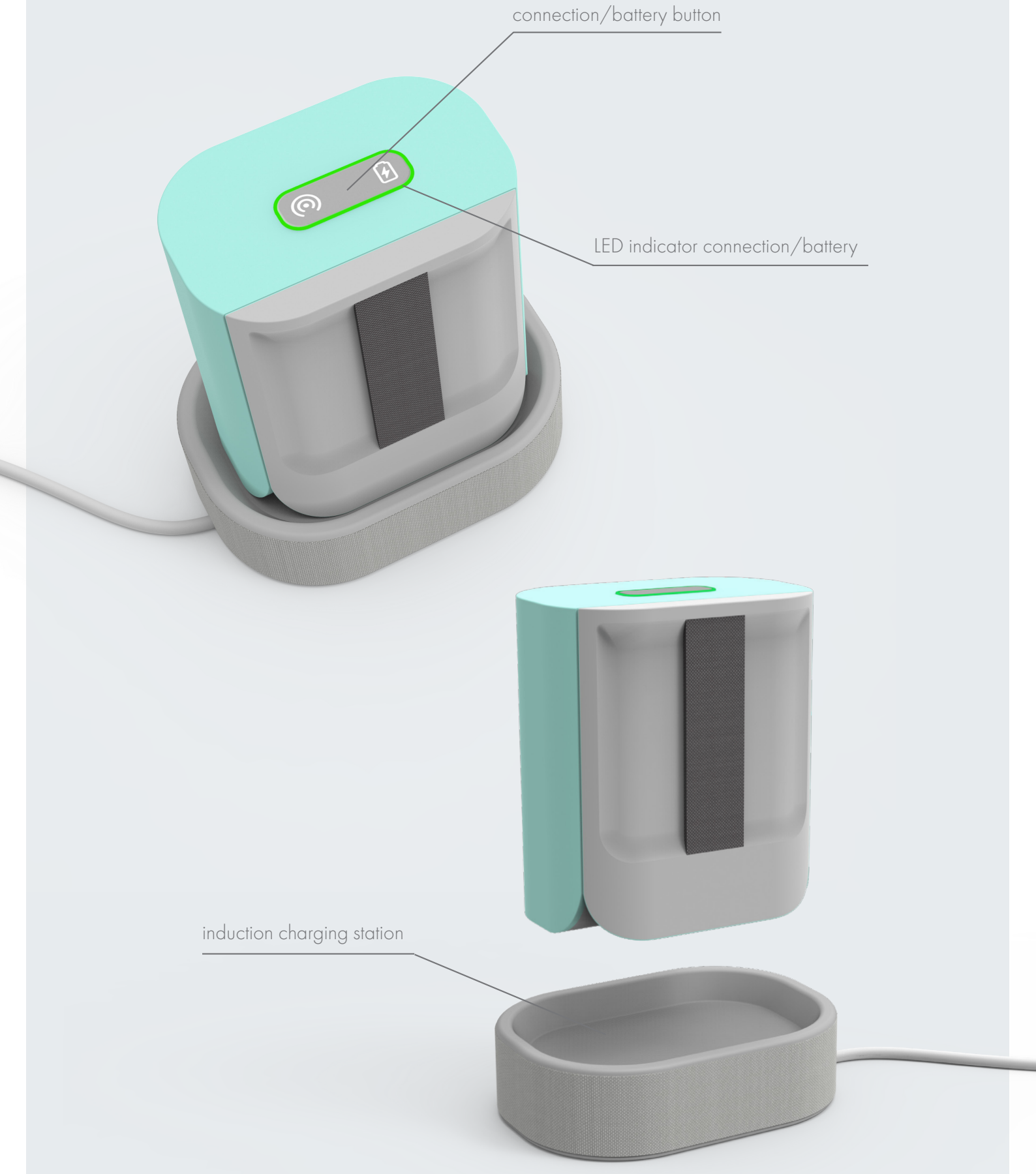


RUBBER DETAILS

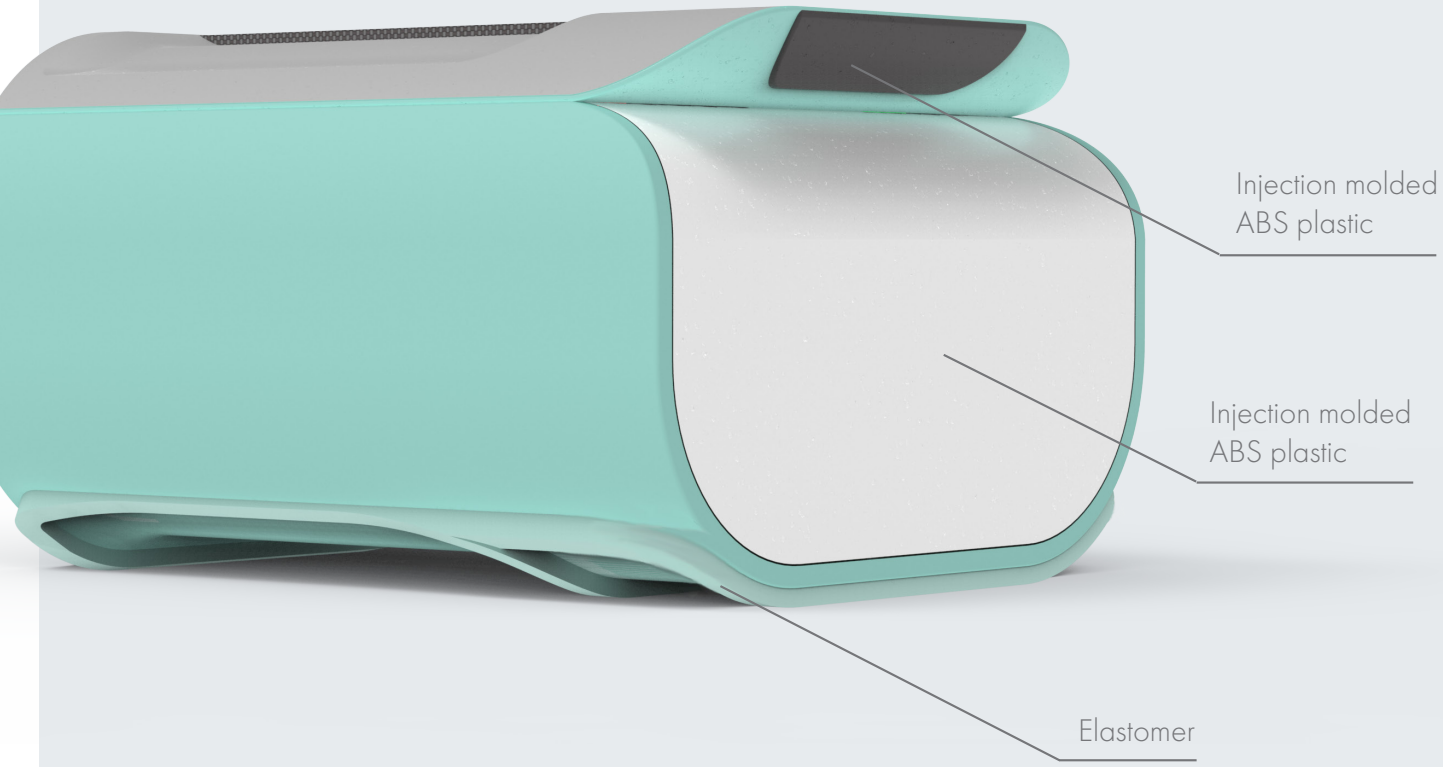


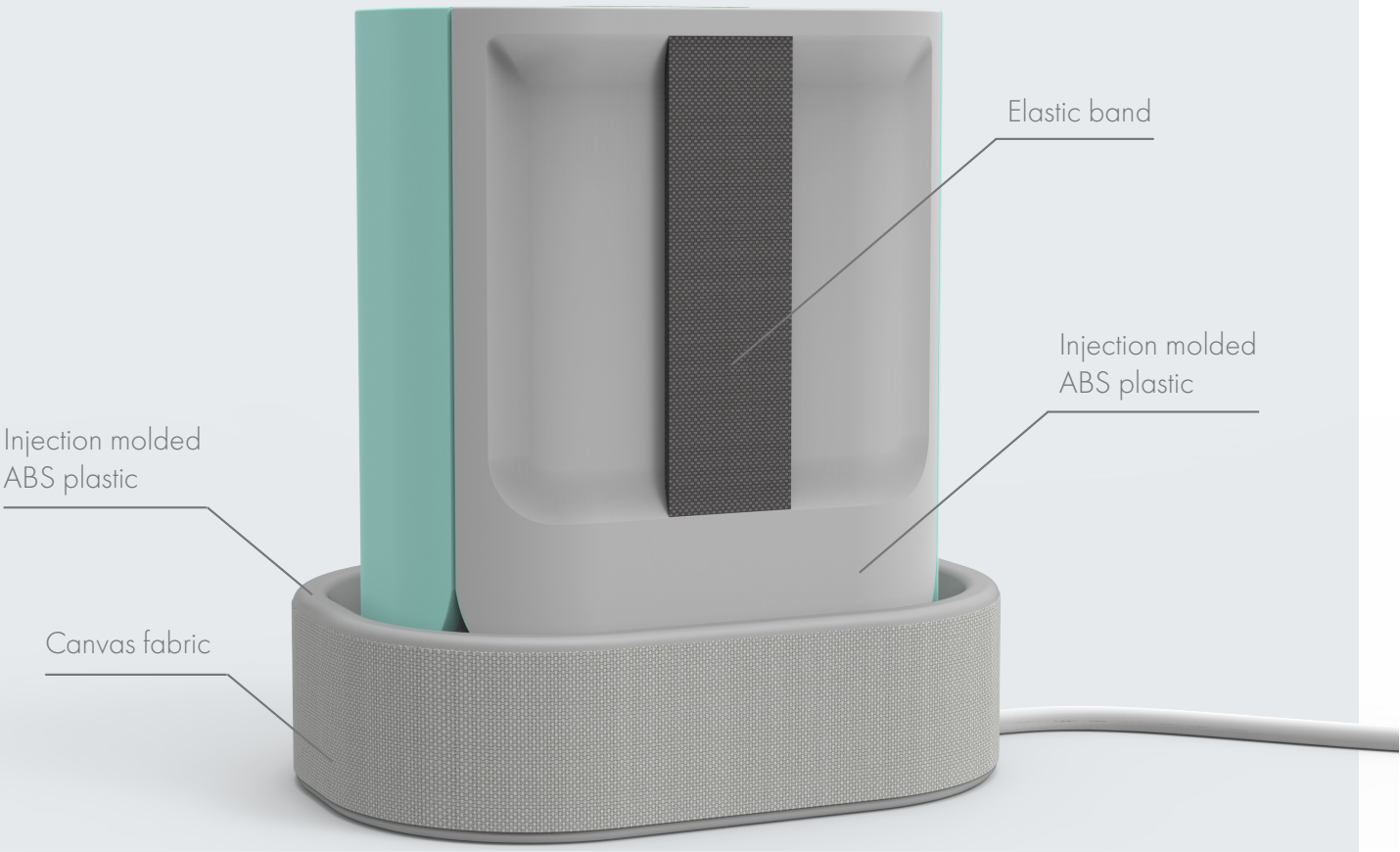


CHARGING


connection/battery button
LED indicator connection/battery
induction charging station

MATERIALS


Injection molded
ABS plastic
Injection molded
ABS plastic
Elastomer


Elastic band
Injection molded
ABS plastic
Injection molded
ABS plastic
Canvas fabric

COLOR VARIANTS

hygiene green

muted red

12.0 RENDERINGS

Keyshot renderings were made to showcase the final concept in real life context scenes, both when used during an emergency situation, and its role in everday life, being stored at home or carried with you.

RENDERINGS

RENDERINGS

RENDERINGS

13.0 REFLECTIONS

Summarized reflections looking back at the main aspects of the project and design process as a whole.

13.1 Perception

Going into this project, I had very limited knowledge of Automated External Defibrillators and Sudden Cardiac Arrest, so I was aware that a lot of research would have to be made. Taking a course in AED helped shape my initial perception, but my views were also continously expanded as the project progressed. For example, I was not previously aware just how common SCAs are, being the single most common cause of death worldwide. Through in-depth interviews, the perception of the target group also broadened, and I learned how widely SCA can affect both victims, risk groups and their families.

13.2 Methods

A big part of this project was focused on the research phases, where a wide variety of methods were used. Desktop research provided a stabile fact foundation as well as technical understanding, while the two surveys provided quantitative data which was especially useful in order to understand the general users and target group. These quantitative insights were used as general indications, which nonetheless helped a lot in steering the project in the final direction and narrowing down the scope and target group.

The first in-depth interviews covered a good range of stake holders, including both experts, amateurs and completely inexperienced users. This resulted in a wide range of insights as well as the possibility of asking spontaneous follow-up questions, making the method more flexible in terms of information-gathering, in comparison with the quantitative surveys.

During the following product development, qualitative data was also acquired through further in-depth target group interviews and small-group testing. This was a great way of getting more specific, as well as gaining more personal insights from the participants and connecting with them on a more human level. As the topic of personal SCA experience is such a private and sensitive subject, it was very humbling getting to hear such personal stories through the in-depth interviews, and thus getting a far better understanding of the target group, as well as identifying needs that would not have been known otherwise. The in-person observation of the mockup tests also played a crucial role in understanding the product interaction and intuitive behaviour in relation to the designs.

Though a wide variety of methods were used throughout the project, they each played a crucial role in bringing the project forward, and in the end there were no methods that did not contribute in some way, no matter if the impact was big or small.

13.3 Production

Due to the COVID-19 pandemic and the ensuing closedown of the school workshop facilities, a final physical model was not possible to produce. Even so, several cardboard and foam mockups were made in order to aid the testing and evaluation processes throughout the project.

Producing these mockups at home came with its own challenges and access to materials and equipment was also limited. Even so, the physical modelmaking aspect of the development played a crucial part in moving the project forward and acquiring tangible insights and direction. These mockups made it possible to put a stronger focus on usability and user experience, aspects which throughout the project really showed their importance in terms of design development rooted in real user needs.

13.4 Complexity

The general complexity of the chosen product category was fairly high, as it related to medical design. And not only medical design, but also focusing on redeveloping a product which is used in life-or-death situations; making the understandability and usability, as well as the technical functionality, of uttermost importance. Due to this high complexity, a long time was spent on initial research, resulting in two extensive research phases. Though this felt neccessary in order to establish a knowledge foundation stable enough for further design development, it did also result in the actual product development starting fairly late in the project.

Since this is a field containing a lot of medical and technical knowledge and research, often of a very high complexity, it was a challenge identifying the point in the research process where enough knowledge was acquired in order to move on to the product development phase. This challenge made it hard moving on to the ideation, leading to a long time spent on research. Even though the knowledge gained from the research phases were incredibly useful throughout the whole project, one could argue that the ideation could have started much earlier, and could have been done more parallell with the research, rather than following it. For a long time, the intense focus on research came with a form of creative block, and if ideation had started at an earlier stage, perhaps this could have been avoided.

So although the high complexity did lead to challenges throughout the project, it also played a huge part in making it such an interesting project, and left me with a better understanding of the medical design field.

13.5 Result

In the end, the project included a physical product, an app interface, and research into technology, medical conditions and knowledge distribution. Furthermore it included a wide variety of methods, such as surveys, interviews, course participation and mockup testing. With all this in mind, the overall project held an appropriate Master's degree level, and the result was a good mix of various skills and methods learned throughout my whole design education; showcasing my acquired skills through a very extensive design process, starting from intial research and ending in final product renderings.

13.6 Reflection

Reflection was an important part of this project. The project as a whole was divided into several phases, and throughout as well as at the end of each phase, reflection was an active part of properly taking in the insights and knowledge gained from the phase in question. Taking the time to do this ensured that these insights and knowledge did not go to waste, but were actively brought into the following phase and applied on the following development. This also created a space for evaluating the progress throughout the project, and learning from my own process while moving forward.

FINAL COMMENTS

Being my Master's degree thesis, this project was a final chance of developing a project which as much as possible showcased my personal skills and design process, before moving on to the professional context where you are more limited by client interests and predefined brand languages. As such, it was important for me to focus on an area of design which represented my desired path moving forward - Medical Design.

With its high complexity and crucial user experience aspect, this was also an area where I found a lot of potential to incorporate a wide range of design methods, and fully show my range as a designer. On a personal level, this project also challenged my abilities and pushed me to develop in terms of project planning, reflection and flexibility.

In the end, the final result and project as a whole contributed to my understanding of myself as a designer, and cemented my interest in User Experience Design and focusing on actual needs and desires; a principle which at the end of the day can, and should, be applied to all types of products.

As this project concludes, I find it to be a true representation of my stance as a designer, clearly showcasing my focus, principles and skills.

THANKS FOR READING